Virtual creation

- Architectural design with virtual reality

MASTER THESIS

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ABSTRACT

Virtual reality (VR) shows promise as an important tool for architecture and design. Recent advancements in the technology are evolving the ways in which the tool is being implemented in the design field. There is a need to research the use of VR in design industry.

The thesis aims to illustrate the possible uses of this new technology by answering the research question of how can virtual reality help designers to improve the design process. The use of virtual reality is examined in detail with qualitative research methods, interviews and observation, and as a tool in a creative process. The hypothesis of the study is that virtual reality is a valuable architectural design tool which improves the efficiency and quality of the design work while also effectively aiding clients, constructors, and fellow designers in understanding the creative vision of design work through all phases of a project.

This study identifies that virtual reality can be utilized in all design phases, reducing risks and saving time and money in design projects. VR is helping to make design decisions, discover design mistakes, comprehend the relations of the spaces and allow designers to prototype their designs in full scale. Virtual reality provides a new tool for designers to express, reflect, represent, market and sell their designs. The outcome of the thesis outlines the process of using VR as a design tool and utilizes the knowledge in the creative process. The creative process of the thesis was created by designing three modular prefabricated houses by utilizing virtual reality as a design tool in the design development phase. Overall, the study strengthens the hypothesis that the use of virtual reality improves the design process and collaboration between clients, designers and the project team. Several challenges, however, can impact the use of VR such as motion sickness, organizational issues and lack of control. Although adopting new technologies such as VR can cause uncertainty and disruptions in the industry, it can also diversify the work opportunities for designers. Future research should focus on overall adoption rates of VR in architecture. In addition, more knowledge is needed on the design phases using VR in wider contexts as well as collaboration of the project team.

Keywords: virtual reality, vr, architecture, spatial design

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TIIVISTELMÄ

Virtuaalitodellisuus (VR) nähdään lupaavana työkaluna suunnittelussa. Teknologian kehittyminen on parantanut työkalun hyödyntämismahdollisuuksia arkkitehtuuristen tilojen suunnittelussa. Opinnäytetyöni vastaa tarpeeseen selvittää uuden teknologian mahdollisuuksia suunnittelussa.

Opinnäytetyön tarkoituksena on selvittää kuinka virtuaalitodellisuus voi auttaa suunnittelijoita parantamaan suunnitteluprosessia. Tutkin virtuaalitodellisuuden käyttöä kvalitatiivisilla tutkimusmenetelmillä, haastatteluilla ja havainnoinnilla, sekä luovan prosessin välineenä. Tutkimuksen hypoteesi on, että virtuaalitodellisuus on arvokas arkkitehtoninen suunnittelutyökalu, joka parantaa suunnittelijoiden, rakentajien ja asiakkaiden ymmärrystä sekä projektin laatua kaikkien suunnitteluvaiheiden aikana.

Tutkimuksessa todetaan, että virtuaalitodellisuutta hyödynnetään kaikissa suunnitteluvaiheissa, se säästää rahaa ja aikaa sekä vähentää riskejä. Virtuaalitodellisuus tehostaa suunnittelua ja auttaa tekemään päätöksiä, löytämään virheitä, ymmärtämään tilojen suhteita ja testaamaan prototyyppiä sen luonnollisessa mittakaavassa. Virtuaalitodellisuudesta on tullut uusi työkalu suunnitelmien ilmaisuun, esitykseen, markkinointiin ja myyntiin. Opinnäytetyössä kuvataan virtuaalitodellisuutta suunnittelun työkaluna ja hyödynnetään informaatiota tutkimuksen luovassa osuudessa. Luova osuus kuvastaa kolmen modulaarisen esivalmistetun talon suunnitteluprosessia, jossa hyödynnetään virtuaalitodellisuutta suunnittelun tukena. Tutkimus vahvistaa hypoteesia siitä, että virtuaalitodellisuuden käyttö parantaa suunnitteluprosessia ja yhteistyötä asiakkaiden, suunnittelijoiden ja projektiryhmän välillä. Virtuaalitodellisuuden käyttöön voivat vaikuttaa monet haasteet, kuten esimerkiksi pahoinvointi, organisaation adoptoinnin haasteet ja VR kokemuksen kontrolloinnin vaikeudet. Vaikka uuden teknologian käyttöönotto voi aiheuttaa epävarmuutta ja häiriöitä, se voi myös monipuolistaa suunnittelijoiden työmahdollisuuksia. Tutkimuksen tulosten pohjalta suositellaan tutkimustiedon kartoittamista VR:n käytön määrästä tilasuunnittelussa. Laaja-alaisempaa lisätietoa tarvitaan myös suunnitteluvaiheiden ja projektiryhmän yhteistyön helpottumisesta virtuaalitodellisuuden avulla.

Avainsanat: virtuaalitodellisuus, vr, arkkitehtuuri, tilasuunnittelu

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CONTENTS

1

INTRODUCTION

Image 1. (You Are Wearing Virtual Reality Goggles 2012).

1

INTRODUCTION

This chapter introduces the subject of the thesis, explains what virtual reality is and how it has been developed. This chapter describes the design project that was created with the help of virtual reality.

1 INTRODUCTION

Experiencing reality is made possible by the combination of sensory information and sense-making mechanisms in the brain. If the senses are provided with made-up information that closely resembles reality, then the brain changes its processing patterns and perceives the information as real. This can be referred to as a virtual reality. Due to technological advancements in recent years, virtual reality can be implemented today using modern computer technology (Virtual reality society 2017). Well-designed virtual reality can create experiences impossible in regular life, improve job performance, cut development costs, provide new worlds to experience, improve education and training as well as create better understanding by walking in someone else's shoes (Jerald 2016).

Jerald (2016) has defined virtual reality as "a computer-generated digital environment that can be experienced and interacted with as if that environment were real". Virtual reality society has defined VR in the following way: "VR presents the senses a three-dimensional computer generated virtual environment that can be explored and interacted with in some fashion" (Virtual Reality Society 2017).

The goal of a virtual environment is to completely engage the user and make them temporarily forget the real world (Jerald 2016). Virtual reality provides an immersive experience in which users can hear 3-D sounds, view stereoscopic images and are free to interact and explore within a 3-D world. A range of different systems such as headsets, treadmills and special gloves (Virtual reality society 2017) can be used to embrace the user in an immersive experience. The outside world can be closed off completely in VR (O'Connell 2016).

The idea of virtual reality goes back prior to 17th century. The Renaissance architects and painters achieved similar goals of spatial illusions with perspective rendering technique (Bertol & Foell 1997). The first modern VR system was developed in 1966 at MIT by Ivan Sutherland. It was the first step towards creating VR beyond the flat screen of the monitor interface and the first computer-based head-mounted display where the sensors recorded the user's head position and movement (Chan 1997).

The first modern VR system created anticipation for its use within the field of architecture. In 1968, the New York Times declared that architects will soon be working in a virtual space creating buildings, walking around them and improving the design (Herzberg 1968 as cited in Paranandi & Sarawgi 2002). The term VR was formalized in the late 1980s and became an established industry by the late 1990s (Paranandi & Sarawgi 2002).

It has only been within the past few years that graphic rendering technology has reached a point to process truly believable virtual reality with viable usability (Bushey 2017). In the late 2010s, VR gained a lot of traction in the gaming industry, particularly with release of sophisticated devices such as Oculus Rift (Ford 2017). The market for the VR has been forecasted to grow exponentially in the next five years (Shirer 2016).

VR has been found to be practical in design and architecture when demonstrating technical competencies, design reviews, simulating dynamic operations, coordinating detail designs, scheduling construction and marketing (Whyte 2007). VR is fast becoming one of the key instruments in design. Evidence suggests that VR could become among the most important tools for design in the near future.

Virtual reality has long been a question of great interest in a wide range of fields. Recently, a considerable amount of literature has risen around the theme of how VR has begun to alter the way people work, train and interact. There is a growing body of literature that recognizes the importance of virtual reality in architectural design and a few studies regarding the topic have been conducted. However, the results of many of these studies have been based upon data from over 10 years ago. The designers who participated in the studies were not using the newest technology and software that is currently available.

New improvements in the technology have changed the way the tool can be exploited in the design field. Recent developments in VR have heightened the need for new research regarding the use of VR in design. Far too little attention has been paid to improve the knowledge of how VR is utilized by the designers. There is a need for a greater understanding of the possibilities of this new technology. The aim of this thesis is to investigate the ways in which VR has been used in the architectural design industry.

This thesis explores the following research question: How can virtual reality help designers to improve the design process? The hypothesis of the study is that virtual reality is a valuable architectural design tool which improves the efficiency and quality of the design work while also effectively aiding clients, constructors, and fellow designers in understanding the creative vision of design work though all phases of a project. The outcome of the thesis outlines the process of using VR as a design tool.

The thesis is a contribution to the field of virtual reality in architectural design. The target audience for the thesis is spatial design and architecture students and practitioners. The purpose of the thesis is to present the design and creative process of three house models and an overview of VR as a design tool. The aim of the thesis is to reveal cases of VR in design and its benefits, capabilities, possibilities and challenges in the architectural design industry.

Qualitative research methods were used to obtain the material for the thesis. The material was collected by interviews and observation. The interviewed and observed design professionals were using virtual reality in their work. The thesis research is closely related to the findings of Whyte (2007) Virtual Reality and the Built Environment and Chan (1997) Virtual Reality in Architectural Design. The thesis presents research studies conducted by Vizpark, Sketchfab and CGarchitects and revenue forecasts from IDC and Super data.

Due to practical constraints, this paper cannot provide a comprehensive review of the VR technology such as hardware and software. The thesis mentions VR in marketing, education and training in the design field, however, it is beyond the scope of this study to examine all of the industries that can be affected by VR. The thesis does not engage with the use of VR in finance, healthcare, retail, transportation, therapy, education, training, fine arts, marketing, telecommunications and media.

The thesis is organized in the following way. The theory and the research findings are presented in Chapters 3-9. The Chapters 3-9 explain the terminology, the adoption of the technology, use of VR in architectural industry, integration of VR in design phases, VR content requirements and the future possibilities of VR in design. The creative process in the thesis is in the Chapters 10-11. This section presents the design process of three modular loft house models designed for MinunLOFT Oy. The Chapters 10-11 describe the benefits and disadvantages of using VR in the design project and how VR affected the design. The thesis ends with the summary, references and appendix.

The main reason for choosing this topic is personal interest. My interest in this area developed while I was working in a video games company, Remedy Entertainment, where I first experienced VR. The opportunity to truly experience how a design will look and feel before commencing construction, design a project in a natural perspective, create a spatial experience without using any natural resources and gain a deeper understanding of the design was the biggest reasons for my interest.

2

RESEARCH PROCESS

Image 2. (Zeitreise Virtual Reality 2016).

2

RESEARCH PROCESS

This chapter describes the research process, literature review and the design project.

This thesis aims to answer the question of how virtual reality can help designers to improve the design process. In addition, this thesis explores the following related questions: What are the benefits and challenges of VR in design? How is VR implemented in different phases of design? The aim of the research is to record how professionals use VR in the design work and determine how VR improves the design processes. The hypothesis of the study is that virtual reality is a valuable architectural design tool which improves the efficiency and quality of the design work while also effectively aiding clients, constructors, and fellow designers in understanding the creative vision of design work though all phases of a project.

The data for this study was collected by qualitative research methods; interviews and observation. The data collected is based on the subjective perspectives of the professionals. The researched topic cannot be fully understood without experimentation. Therefore, observation provided a deeper understanding in the use of VR. The knowledge on how to operate the new technology as a design tool was recorded in the Chapters 3-9 but also utilized to perform the creative part, Chapters 10-11, of the design project. A literature review analyzed studies that elaborate on the use of VR in creating spatial design.

Not all of the interviews, observations and meetings could be recorded. The missing recordings can create a for potential researcher bias and might impact the reliability of the findings. Further studies need to be carried out in order to validate the thesis results.

2.1 Literature review

A considerable amount of literature has been published on how VR has begun to alter the way people work, communicate, learn, train and interact. Over the past two decades, major advances in hardware and software technology have allowed professionals to explore the possibilities of using virtual reality as a tool. A great deal of previous research has focused on explaining the technology and creation of immersive VR applications.

Hale and Stanney (2017) and Jerald (2016) have analyzed the development of VR technology and the system requirements in creating VR applications. Both studies have examined the association between human perception and VR applications. Hale and Stanney have argued that creating immersive VR experiences requires cognitive design strategies. The study combined a comprehensive set of articles that address the principles of creating VR applications (Hale & Stanney 2017).

These two studies indicated that a great deal of planning is required in creating an immersive VR environment. The studies remained narrow in focus dealing mostly with the entertainment industry. However, these studies provided important insights into how architects and designers can exploit VR as a communication tool.

Around ten years ago, small-scale research and case studies began to emerge, linking VR to design processes. Clerk, Wijk and Ligtenberg (2003) investigated the use of VR in the landscape design process. Kulkarni, Kosse, Kapoor and Iyer (2009) focused on VR in car design. The study investigated a design validation process for physical objects (Kulkarni, Kosse, Kapoor & Iyer 2009). All of the studies reviewed support the hypothesis that VR has been a beneficial tool for the design process and assessing the design. Although the previous research on VR in design has focused on identifying and evaluating the new tool, only a few writers have been able to draw systematic results in describing VR in several design cases.

A growing body of literature has recognized the importance of virtual reality in architectural design (Whyte 2007, Chan 1997, Bertoll & Foell 1995). However, there has been a relatively small body of research that is concerned with designing spaces with virtual reality. A significant analysis and discussion on the subject was presented by Whyte in 2007. Whyte explained the benefits of VR as a design tool and how it serves professionals, supply chains, clients, managers and end-users. The study demonstrated the use, the development and the future of virtual reality in designing the built environment. The study collected data from practices around the world (Whyte 2007). Cambell (2003) demonstrated how VR has been used throughout one architectural design process. Chan (1997) described how VR has been applied in architectural design and how it has been a powerful new medium of expression for architects and designers. The paper presented the history of VR until 1997 (Chan 1997). Because virtual reality technology has improved extensively over the last ten years, more studies are needed to explain the usage of VR in creating architectural design.

More recent attention, articles and achievements of VR in design have been found in web forums, VR social media groups and web magazines. Dezeen and Archdaily web magazines have begun to report about the use of VR in architecture and how to start designing with VR (Virtual Design 2017 & Virtual Reality for Architects 2017). Studios and organizations have started to share more details about their work flow with VR (O'Connell 2016 & Hobson 2014 as cited in Mairs 2016). Annual conventions and exhibitions such as Siggraph and VRLA have presented the latest innovations.

Several lines of evidence suggest that the architecture industry has been increasing the use of VR. However, a limited amount of quantitative research data has been found on how much VR is used in the architecture and design field. In recent years, four studies have identified the increased use. The studies were conducted by Vizpark, IDC, Sketchfab and CGarchitects in 2016 and 2017. The surveys of CGarchitects, Vizpark and Sketchfab were conducted via the websites, newsletters and social media. The focus groups of the surveys were registered clients, which can generate distorted survey results. The registered people were already technology oriented and interested in VR.

This thesis will create a comparison between previous case studies, theory and findings of the thesis research. The information of the interviews will be presented and compared with the literature in the Chapters 3-8. The information gathered in the theory part has been used to implement VR in the creative process of the modular houses.

2.2 Interviews

The initial sample consisted of three architecture company representatives who were creating buildings and interiors using VR. The inclusion criteria for the participants changed after meeting with professionals from different fields of design, all of whom create spatial experiences with the help of VR. The meetings with video games designers and VR studio representatives were going to be pilot interviews to understand the topic and not to be recorded in the thesis results. However, the interviews captured the complexities of VR as a tool in design. Architects, designers, video game designers and architectural VR software developers were all tackling the same questions in using VR as a tool for design.

A major advantage in analyzing the perspectives of designers in different fields is that it gives a deeper understanding of the changing role of the designer as well as the change of the industry. The meetings with these specialists have illustrated how VR has created new professions and markets for designers and architects, and how the role of a designer can be expanded towards creating virtual experiences. Further data collection is required to determine exactly how VR affects the profession of designers and architects.

2.2.1 Interviews in the architecture companies

Information about Finnish architecture companies using VR in their design process was not found during the literature review in the Spring 2017. The solution was to conduct in-depth interviews with designers and architects in Los Angeles. The interviews with two architecture companies were performed using semi-structured questionnaires. The interviewed professionals have been using virtual reality technology for several years in their work. They have been recognized as forerunners of using VR in architectural design. The interviewed professionals have been touring industry conventions as keynote speakers and are working as advisors for architectural VR software developers. The data was recorded on a digital audio recorder and transcribed in the thesis.

The focus of the thesis is on the architectural design. Therefore, the interviews with the professionals in architecture companies have more coverage in the thesis results. The interviewed professionals in the architecture industry are Interviewee A, Gensler's firm-wide visualization director and Interviewee B and C, a VR Architect and a Project designer at TCA Architects.

The studied architecture companies have implemented VR in their current design work flow. (Appendix 1 & 2). Gensler is an American architecture and design company. The company operates in 16 countries, has 46 studios around the world with its headquarters located in San Francisco (Appendix 1). The company has the largest revenue of any architecture firm based in the United States for fifth year in a row. Gensler's revenue was $1.18 billion in 2016 (Top 300 Architecture firms 2017). Gensler has total of 4600 employees and the Los Angeles office employs 600 people (Appendix 5). TCA Architects is a smaller architecture company based in California, USA. The company has studios in Orange County, Los Angeles and Oakland. TCA Architects has approximately 100 employees (TCA Architect 2017).

2.2.2 Interviews with VR designers in other industries

By broadening the preliminary research group, the results became heterogeneous. A simpler focus group could have given more centralized results. However, VR has created new professions and markets for designers which justified the decision to use interview results of professionals who are not working in the architecture industry but creating spatial experiences with VR.

The interviewed professionals have created virtual environments for VR such as video games, spatial experiences and architectural tools. The professionals are architects, designers, visual effect artists and entrepreneurs that have years of experience in working with VR. The professionals have experienced a substantial change in their professional roles due to VR. The informal interviews were not recorded with audio recorders but the notes of the interviews are enclosed in the Appendix.

Informal interviews were conducted with VR application provider Teatime Research, VR games company 3rd Eye Studios, Disney Imagineering and VRLA. The interviews revealed information about using VR in the design process and how VR has opened new markets and ways of working for designers. The evidence reviewed here seems to suggest that learning how other industries are using VR as a tool, benefits the designers in the architectural design industry.

Teatime Research Ltd is a Helsinki-based company and it designs virtual reality applications, interactive software solutions and services for clients such as ALA Architects and YIT. The Interviewees F and G are the CEO and COO of the company (Appendix 4). 3rd Eye Studios is a VR video games company based in Helsinki. The company is creating interactive storytelling games with VR and the founders Interviewee D and E are the CEO and Lead Artist in the company (Appendix 3).

Disney Imagineering is creating and building the designs of Walt Disney Parks and Resorts such as theme parks, real estate developments, attractions and regional entertainment venues worldwide. The company employs creative and technical professionals (About Imagineering 2017). Interviewee H from Disney Imagineering creates ride designs with VR for Disneyland amusement parks. Interviewee H's background is in visual effects, and she has been working as a Visual effects artist for movies such as The Amazing Spider-Man, Divergent and Maleficent (Appendix 6).

VRLA is the worlds largest VR convention for consumers and industry professionals held in Los Angeles (VRLA 2017). Interviewee I is a CEO of VRLA and also works with VR in the movie industry. Interviewee I has developed virtual production pipelines for many of the leading companies' like Id Software and Epic Games as well as for movies 'The Jungle Book' and 'Ready Player One' (Appendix 6).

2.3 Observing

Observation has been used for evaluation when the aim is to understand an ongoing process or a situation. Observational research findings have considered to be strong in validity because the researcher is able to collect in-depth information. However, the reliability, generalizability and researcher bias could generate problems (Observational Field Research 2017).

Data was obtained through direct observation in the interviewed companies and unobtrusive observation in VR events. The observation situations were not recorded with audio recorders. The notes of the observations have been enclosed in the Appendix.

During the visits to the interviewed companies, several VR applications were tested and reviewed. VR was used as a tool to communicate and illustrate the work of each company. Gensler, TCA Architects, 3rd Eye Studios and Teatime Research each provided several VR experiences that presented an immersive experience for the user. The VR experiences demonstrated how VR is used in the companies.

The direct observation data was gathered in Gensler LA during a discussion about "Scale models vs virtual reality" and the company-wide weekly virtual meeting called "VR Jam". The observed discussion and VR Jam was held in June 2017. The discussion was participated by 20-25 Gensler architects and designers and it lasted an hour. The discussion revealed architects opinions of designing with VR, how VR has changed the design work and how the designers see the future of VR. The VR Jam was an hour-long meeting with 10 participants from different Gensler studios around the USA. The participants communicated with each other using a speaker-phone and the VR system. The VR jam meetings were created to share information throughout the company about the use of VR in design (Appendix 5).

The thesis has included data from events such as VRLA 2016, Upload VR in July 2017 and Siggraph in August 2017. VR events and conventions displayed VR case studies, demos and latest innovations in the VR industry.

VRLA is the world's largest VR convention. It presents the latest trends from VR & AR experts across two days of panels, presentations and workshops (VRLA 2017). Siggraph is the world's biggest conference and exhibition in interactive techniques and computer graphics. The annual convention presents demos, art, research results, educational sessions and hands-on interactivity and features of the latest technical achievements. The commercial exhibit part displays the industry's current software, hardware and services. (Siggraph 2017). Upload VR is a multi-faceted company that focuses on accelerating the growth of VR and AR industries. The company provides spaces for incubation, education, co-working and VR related events in Los Angeles and in San Francisco (Upload 2017).

2.4 Experimental and Creative process

The artistic component in the thesis is the design of three loft houses for MinunLOFT Oy. The design goal was to develop three different prefabricated house models that utilize the same modular system and are built with a steel structure. The design project has started in October 2016. The process began with a research about the modular prefabricated houses and visual references for the design. The design project proceeded with concept design, schematic design and design development phase. The design development was utilizing HTC Vive as one of the design tools. During the design process, a design journal was kept about the thoughts and challenges in the process.

The outcome of the creative process is presenting the first renderings for the house models, module floor plans, architectural visualizations and advertising materials such as magazine ads and client brochures. The models have been presented to the public in the Summer of 2017 during the Mikkeli housing fair. The design of the tailor-made homes will be further developed during the year 2017 with a structural engineer and a licensed architect. The first demonstration model will be built in the Spring 2018. The construction of the house models will start in 2018.

LITERATURE & RESULTS OF THE INTERVIEWS AND THE OBSERVATIONS

3

VIRTUAL REALITY IN A CONTEXT

Image 3. (Curtis 2015).

3

VIRTUAL REALITY IN A CONTEXT

This chapter describes the terminology related to virtual reality. The chapter begins with a descriptions of augmented reality, mixed reality and augmented virtuality and moves on to portray a description of the VR equipment.

3.1 Augmented reality, augmented virtuality and mixed reality

Augmented reality (AR) has been defined as presenting an animated digital data over the real-world view (O'Connell 2016). AR adds cues onto the already existing real world and preferably the computer-generated stimuli will not be distinguished from the real world. Augmented reality can be seen through a tablet, a smart phone (O'Connell 2016) or AR glasses such as Microsoft HoloLens (Appendix 2).

There have been a number of augmented reality game applications such as a Pokémon Go app (O'Connell 2016). However, AR has proven to be a valuable tool for professionals as well. For example, an engineer on the construction site has been able to place studs in the correct locations by looking the site through the AR glasses (Appendix 2). AR has been applied in interior architecture by showing virtual furniture in the existing space (Lee 2017) such as with an IKEA Catalog AR App or using services of online-only design company Decorilla. SmartReality and Augment applications have created an instant 3d model on a table through a smartphone or a tablet (How reality technology is being used in design 2017).

Although AR is a beneficial and competent tool for design and construction, Interviewee B has believed that VR will have a stronger hold in the architectural and design industry (Appendix 2). Strong evidence of this was found when respondents rated VR's potential as more compelling compared to AR. The respondents preferred VR system to AR system (VR industry trends 2017 & Figure 1).

International Data Corporation (IDC) has identified the primary market segments for augmented reality and virtual reality. Architectural design services could be applicable in five of the segments; discrete manufacturing, process manufacturing, resource industries construction but most of all professional services (IDC 2017 & Figure 2).

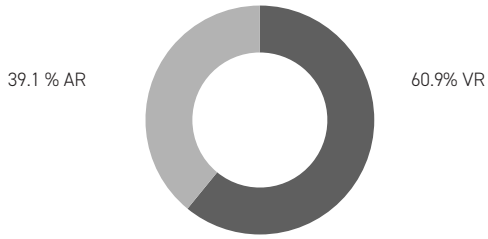


Fig. 1. Are you more interested in the potential of VR or AR?

(Virtual industry trends 2017)

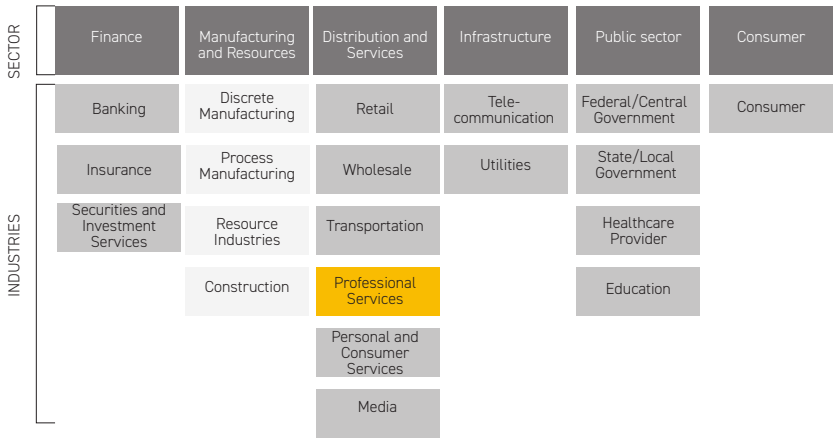


Fig. 2. AR and VR Primary segments (adapted from IDC 2017)

Mixed reality (MR) has been defined as "a hybrid environment that combines real and digital objects together in real-time" (Kilkelly 2017). Mixed reality has blended AR and VR together by overlaying virtual objects onto the real-world. A notable example of MR is, that it has been used by professionals to communicate multi-dimensional and complicated information. A structural engineer at the construction site in Helsinki and an architect in her office in Los Angeles could communicate and interact together while seeing the designed virtual building in front of them (O'Connell 2016).

MR has expedited the construction work by displaying an x-ray of the existing building for the constructor. If the virtual model of the building has been accurate and correctly in-place, an engineer has seen how the existing walls, floors and ceilings are built (Appendix 2). CO Architects, an architecture firm based in Los Angeles, has used Mixed reality to develop a solar calculation tool (Kilkelly Michael 2017).

Milgram and Kishimoto (1994) placed virtual reality to a Reality-virtuality continuum. The Reality-virtuality continuum Figure shows VR's relation to augmented reality, augmented virtuality and mixed reality (as cited in Jerald 2016 & see Fig. 3). Augmented virtuality (AV) has been defined as a technology that brings real-world content to virtual reality (Jerald 2016).

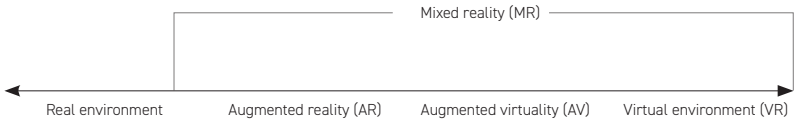


Fig. 3. Reality-virtuality continuum

(Milgram & Kishinmo as cited in Jerald 2016)

3.2 Defining immersion, interaction and navigation

Witmer and Singer (1998) have defined immersion as "a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences". Immersion is specifically a psychological experience in which the role of interaction and stimuli is emphasized. An immersive VR experience is a coherent, interactive and compelling virtual environment that presents a meaningful continuous stimuli to the user (Hale & Stanney 2017). Immersive systems surround the user and provide a supposedly unmediated experience (Whyte 2007).

Interaction in VR has two dimensions: navigation and the dynamics of the virtual environment. Navigation means the ability to move independently around the environment and the dynamics is positioning of a user's point of view. For example, dynamics could be used to move in a wheelchair through the design to test the accessibility (Chan 1997).

3.3 VR Equipment

Virtual reality systems today can be implemented with three display systems: handheld displays, world fixed displays and head-mounted displays. Hand-held displays are devices that can be held with hands and don't require tracking or alignment with the eyes. The hand-held augmented reality have become popular because of smartphones and tablets (Jerald 2016). World-fixed displays do not move with the head and can take many forms from a standard monitor to displays that surround the user (Virtual and Augmented Reality 2017).

A head-mounted display (HDM) is a visual VR display that is attached to the head. The HDM creates an essential immersion of the VR space for the user and interacts with the user's motions by tracking the position and orientation of the head. HDM's display updates the current pose of the head and earphones play the audio that follows along with the motion of the head (Jerald 2016). The head-mounted display takes advantage of the humans' ability to merge images presented to the two eyes into a 3D image. The head-mounted displays differ in impact of color, field of view, light filtration and cost (Hale & Stanney 2017). The thesis focuses on VR using head-mounted displays and the creative portion has been performed with HTC Vive headset. The Vive headset is regarded to be the best VR display currently in the market (see Fig. 4).

VR used to be highly expensive hardware (Kilkelly 2017). However, in the last few years, the prices of head-mounted displays have been brought down which has made VR displays such as Oculus Rift, Samsung Gear VR and HTC Vive more mainstream. The industry got a highly evident boost from Facebooks acquisition of Oculus for $2 billion in 2014 when Facebook lowered the cost of Oculus Rift VR system to $399 (O'Connell 2016 & Reid 2017). HTC Vive headsets can be purchases with $600. VR systems using Google cardboard headsets and smartphones are progressively popular (see Fig.5). Google Cardboard offers an inexpensive way to present stereo 360 panoramic images of the design. (O'Connell 2016). Google Cardboard costs $15 dollars (Kilkelly 2017).

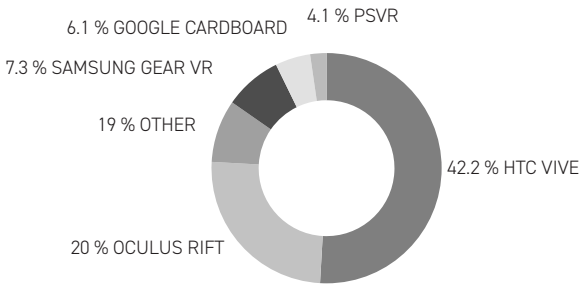


Fig. 4. What is your favourite VR equipment?

(Virtual industry trends 2017)

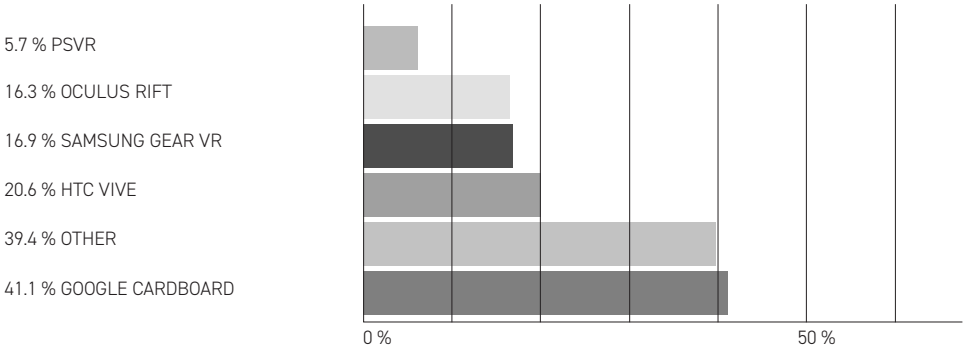


Fig. 5. Which VR equipment do you own?

(Virtual industry trends 2017)

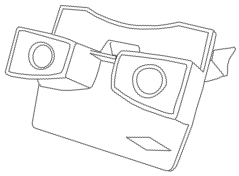
I addition to tracking the location of the head, there are multiple different gear to track the location of the user's hands, legs and body. Usually the HDM is accommodated with a hand controller that lets the user interact with VR (Siggraph 2017).

Two classes of technology have been utilized to play sound in the virtual environment, loudspeaker-based systems and headphone-based systems. The objective of a sound system in VR is to create a realistic perception of a 3D acoustic world at the eardrum (Hale & Stanney 2017).

Special VR hardware requires a high-end computing power to run high quality virtual environments (Whyte 2007). Currently VR-ready laptop can be purchased with 2000 euro (Appendix 4).

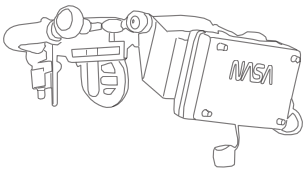
An essential component of the VR system is the 3d content. 3d models can be modeled within VR or imported from CAD. 3d laser scanning, photogrammetry or geometry capture can be used to obtain 3d versions of the physical world (Whyte 2007). Technology has surpassed the human visual limits in every territory, and the display technologies can present solid and immersive visual environments (Mortensen 2008 as cited in Hale & Stanney 2017).

The advancements of the VR technology have improved the VR experience, rendering and immersion quality (Siggraph 2017). The Figure 6 shows the progress of VR from 1939 onwards (see Fig.6).



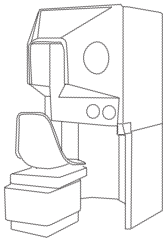
1939: GAF Viewmaster

Stereoscopic 3D



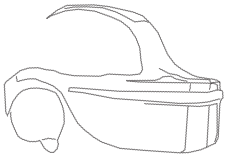
1985: LCD optics & head tracking

NASA



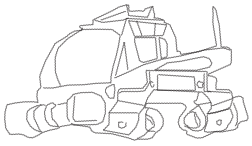
1956: 3D displays

Sensorama



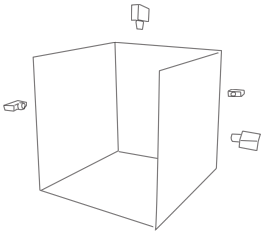
1993: VR console gaming

SEGA VR



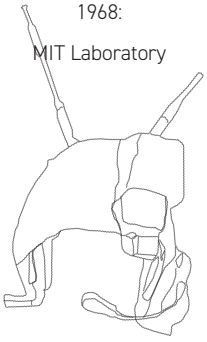
1968:

MIT Laboratory



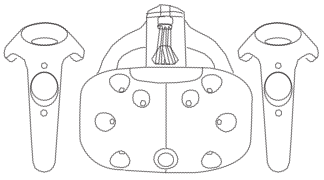
1995: CAVE – Multiple users

University of Illinois



1980: Wearable computer

Steve Mann



VR in 21st century

Fig. 6. The history of VR equipment

(adapted from Axworthy 2016)

4

ARCHITECTURE AND DESIGN STUDIOS ADOPTING VR

Image 4. (The Head-mounted Display 1968).

4

ARCHITECTURE AND DESIGN STUDIOS ADOPTING VR

This chapter demonstrates the adoption of a new innovation. The chapter describes how the VR is diffused at the architectural studios.

4.1 Adoption of an innovation

Merely a few innovations have spread from the first introduction to universal use in a few years (Rogers 1995). Previous studies have evaluated the factors that affect the adoption of an technological innovation, its attributes, the adaption of the society and the adopters characteristics. Rogers (1995) identified several attributes that affect the adoption of an innovation. The attributes are relative advantage, compatibility, complexity, trialability and observability (Rogers 1995).

Relative advantage is defined as the perceived gain of the innovation in relation to the idea it has replaced. The relative advantage could be indicated as the degree of social prestige and economic profitability. Compatibility is defined as a degree to which an innovation is perceived as coherent with adopters values, needs and former experiences. Complexity is defined as the level of difficulty to understand and use the innovation in relation to the adopters skills. Trialability is defined as how the innovation can be experimented and tested. It means that the adopter can erase possible uncertainty regarding the new idea. Rogers defined observability as how visible the innovations gain and outcome are to others (Rogers 1995, see Fig.7).

ATTRIBUTES OF INNOVATION

1. Relative advantage
2. Compatibility
3. Complexity
4. Trialability
5. Observability

Fig. 7. Attributes of innovation

(Rogers 1995)

The innovation of the technology is only one factor in deploying a technological innovation in the society. Greater factors are needed to be enforced in adoption of a new technological innovation. Even if the innovation offers a relative advantage, compatibility to the needs and values of the user, understandable and tested solutions or visible results, the user of the society can still make the decision not to use the innovation. The external forces from the technology itself affect the adoption of a technology in the society. These are the push of the innovation, the society, technology utility, moral attitudes, economic factors and consumers pull (Hale & Stanney 2017, see Fig.8).

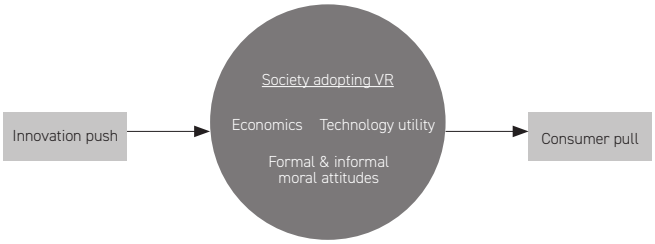


Fig. 8. Technology's diffusion in society

(adapted from Hale & Stanney 2017)

Economical factors of the user and the formal and informal moral attitudes affect the diffusion of the technology. The current overall technological progress and the demands of the consumers enforce the endorsement of the new innovation (Hale & Stanney & see Fig.8).

Rogers (1995) explained how the innovation will get diffused in the society over time. Rogers (1995) categorized the adopters to five different user groups in using a Bell's curve which shows the normal frequency distribution. This curve is divided in innovators, early adopters, early majority, later majority and laggards (Rogers 1995 & see Fig.9).

The categories represent the approximate percentage of individuals included in each phase. Innovators are risk-takers who are eager to try new ideas and control of substantial financial resources. Innovators are able to understand complex technical knowledge and cope well with uncertainty. Early adopters are a more integrated part of the social system and are the opinion leaders and role models of other members in the social system. The early majority adopts innovations right before the average member and interacts often with people. Late majority adopts the innovation after the average person and adoption could be a cause of a network pressure and an economic necessity. Laggards are last to adopt the new idea. Laggards don't have opinion leadership, are not part of the social networks and have traditional values (Rogers 1995, see Fig.9). It could be said that all the interviewed professionals belong to the first two groups of the Rogers categories.

All the significant adopted technology have transformed how the society works. For example, the adoption of automobile technology changed all the aspects of modern life. Some of those changes were appreciated and anticipated nevertheless others were not welcomed. Transformation is certain within deploying a new technology. By understanding how the society and organizations adopt innovations, the discouragement of deploying a new technology can be reduced (Hale & Stanney 2017).

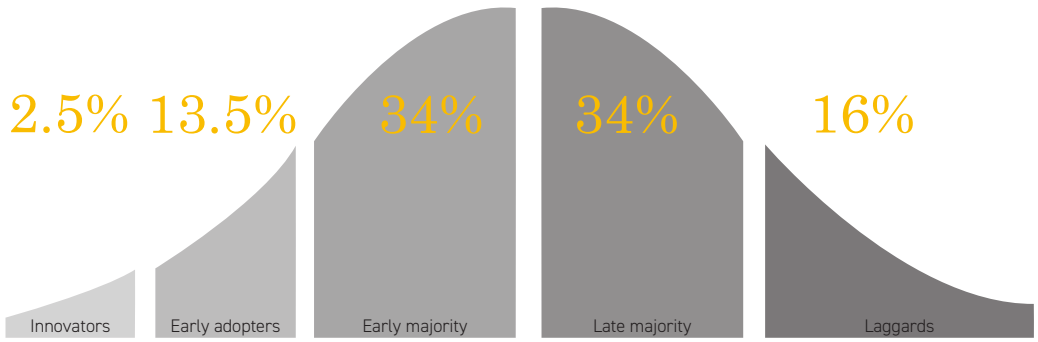


Fig. 9. Innovativeness and adopter categories

(Rogers 1995)

4.2 Adoption of VR

Computer scientists have been studying the VR technology such as head-mounted display devices (HMDs), touch sensors, processing speeds, and spatial cognition maps for a long time, but the mainstream adoption of VR has been rather slow (Ford 2017). VR technologists push to deploy VR because the innovation has a potential for enhancing the way people live and work (Hale & Stanney 2017).

Blascovich and Bailenson (2011) disputed that it is a basic human need to fantasize, imagine and escape. VR technology appeals to these basic human needs. VR is a mode of media, in addition to sculpture, graphics, storytelling, theater, cinematography and photography etc. VR technology has promised many new experiences from radiant visuals to compelling surround sounds that could be harnessed to change the user's brains via therapy or training. VR could be used to teach art or science and cure phobias. Yet along with the promise of VR, there are potential drawbacks related with VR exposure: bright lights, negative emotions, motion sickness, loud sounds, phobia induction and destructive tendencies. Developers are trying to minimize the adverse effects of VR interaction with common sense and research (Hale & Stanney 2017).

Cost of the technology as well as anachronistic wire attachments can be the reasons that prevent the VR technology mass adoption (Ford 2017). The mass adoption of VR could be possibly obtained thought inexpensive hardware, better content, improved distribution and solution-oriented applications (see Fig.10). The most popular use of VR is gaming. However, exploring environments, content creation and 360 videos are significant uses of the new technology (see Fig.11). The results further support the idea that VR is a valuable tool for architecture and design.

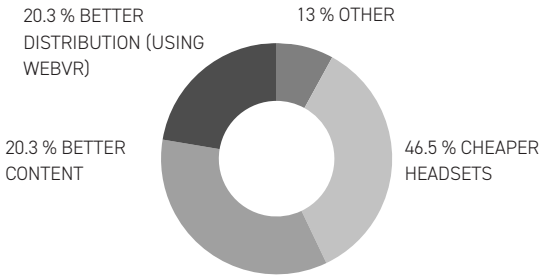


Fig. 10. How can VR reach mass adoption

(Virtual Industry Trends 2017)

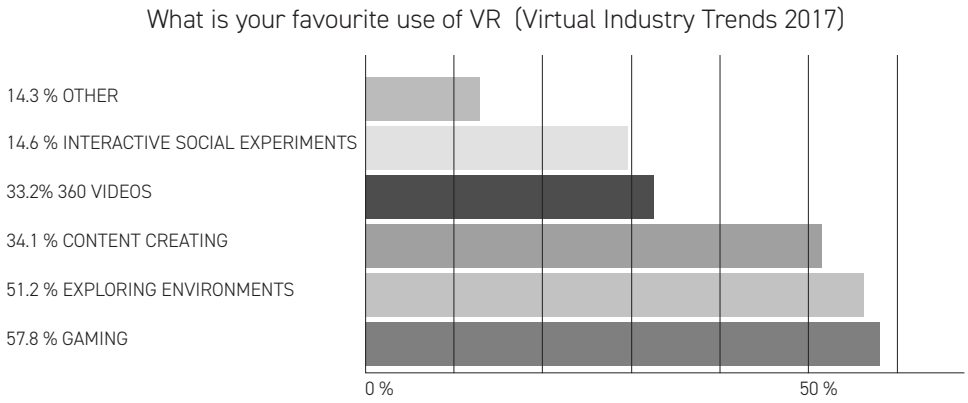


Fig. 11. What is your favourite use of VR

(Virtual Industry Trends 2017)

The adoption of VR has created expenses for the design studios. Setting up a VR equipment has been relatively cheap however creating the content, purchasing the software and maintaining the use of VR can be expensive. The research of the new equipment, working methods, education and training can exceed the resources of a smaller design studio (Hale & Stanney 2017). The costs of VR have been dependable of the adoption level of the organization and the size of the design project (Whyte 2007).

4.3 Adoption of VR in Design studios

Adopting a new technology has brought new requirements for architecture and design companies. Adoption of the technology has meant investing in the training of the staff and deciding multiple different goals for the use of VR. The various goals can be adjusted for marketing, design, virtual mock-ups and high-quality models. The design company CannonDesign has started to adopt VR by outlining the goals. The company assessed the required technology and understood that each goal had their own investment level in the company. CannonDesign started to adopt the technology after the clients requested the use of VR in building models. The company increased investment in the technology and utilized it for client presentations and as an exploring tool for the designers. Designers have valued the use of VR (Kilkelly 2016).

The architecture and design companies are exploiting VR in different emphasis. Hickok Cole Architects in Washington D.C. has used VR in design, presentations and marketing. The company began the exploring of VR through in-house iLab program which provided a micro-grant for its employees to research VR. Hickok Cole has been using VR on a few projects. Boston-based Payette has posted VR-related information in their intranet and placed a dedicated VR space in their lounge space, where anyone can try out the software. An architecture and engineering company, LHB, has begun to increased the use of VR and has a dedicated VR lounge for the staff to test the technology (Kilkelly 2016).

Companies have not shared detailed data about the usage of VR so estimating the overall usage is challenging. Whyte argued that the use of VR will increase when organizations notice that competitors use the technology and regulators and customers demand or expect the company to provide the technology as a service (Whyte 2007). Interviewee A forecasted that the competitors who haven't started to adopt VR, will encounter complications in the future. The studios that don't excel the use of VR will loose design projects to the ones who have adopted the technology (Appendix 1). Clients have a major role in how the technology will be adopted in the architecture industry. Losing projects to companies that use VR drives the motivation of slower adopter companies to adopt the innovation (Appendix 2).

When the architecture company adopts the use of VR, educating and training the whole staff is important. This ensures that everyone understands how much VR can help and what can be accomplished with the technology. Educating a wide group of designers and business development and marketing staff helps client-facing leaders to understand the hardware and software limitations before they agreed to VR deliverables (Kilkelly 2017).

The evidence presented thus far supports the idea that the adoption of VR is in the phase where the early majority has started to adopt the innovation. However, adoption of the technology has not yet reached the critical mass.

4.3.1 Adoption of VR in Gensler

At Gensler, the adopting of VR started by introducing the technology to the designers and managers. The designers and managers became excited about the possibilities, quickly discovered the usefulness of the tool and wanted to invest more money in the headsets and software. Some of Gensler's clients requested for VR which created more interest towards the technology among the designers (Appendix 1).

Gensler has noticed that the adoption of the technology has been time consuming. Three firm wide visualization directors have created training material, instructions and procedures of the use of VR however the information flow in a 4600 employees company is challenging and spreading the awareness of the technology has not been simple. For example, a client requested details about VR, but a designer had been unaware of what VR was even though the technology had been already used in the company. Loosing a project to a competitor who used VR in their design pitch has helped to drive the use of the tool and to clearly see the benefits of the technology (Appendix 1).

Gensler has tried to make the adoption of VR simpler for the designers with one-click-VR-solutions software such as Enscape. The company has invested in creating good training material that the entry barrier of learning a new technology is low (Appendix 1).

Gensler has added one VR rendering as a minimum for every project. Each designer has taken the responsibility of the visualization of the project and has chosen the level of quantity it is utilized in the project. Some designers have endorsed the new tool whereas others have been more hesitant to take a new tool in their work flow thinking that it might slow the design process. Because VR has been utilized more in the company and it is trending online and in the news, more people have been intrigued to exercise VR to their advantage in the design projects (Appendix 1).

Gensler has dedicated VR spaces that have been treated much like conference rooms. Designers have reserved the rooms for presentations with clients or for internal design reviews through a booking system and received the equipment from the IT. The company has organized weekly VR Jams, where the designers can meet, discuss and share information about the design projects. The company has used the VR jam for education and training purposes. Around 30 people have participated in the VR jam every week (Appendix 1).

Gensler's major offices have invested in many head mounted-displays, because the pricing of the technology is relatively inexpensive. The VR equipment has been continuously reserved and utilized. Interviewee A has believed Gensler to be far along in the adoption of VR but the industry is changing rapidly and carrying on with the development requires attention and investment. Interviewee A has forecasted that the use of VR will grow in the future (Appendix 1).

4.3.2 Adoption of VR in TCA Architects

The CEO of the TCA Architects has made a conscious decision that the company affiliates their services with VR. The adoption of VR has started in the Oakland office. The deployment of VR is limited in the LA and Orange County offices but VR has been diffused throughout the company (Appendix 2).

TCA Architects has seen the benefit of VR in the design process. The company has invested in the adoption of VR because of it offers relative advantage. Relative advantage of VR is that the technological competence creates possible revenue in the future. TCA Architects has been using VR in marketing, design development and reviews. The architecture company has adopted the software very largely in their work flow. TCA architects has used VR spaces weekly for design reviews and meetings with the client (Appendix 2).

The use of VR has not been mandatory in the company. The designers have chosen their approach in the use of VR. However, Interviewee B has forecasted a change in the matter in the near future and argues that the company isn't gaining the value of VR until the whole staff is utilizing the technology to its full potential (Appendix 2).

5

ARCHITECTURE AND DESIGN STUDIOS UTILIZING VR

Image 5. (Orland 2013).

5

ARCHITECTURE AND DESIGN STUDIOS UTILIZING VR

This chapter demonstrates the use of VR in the architecture and design studios. The chapter describes how the organizations can benefit from using VR.

5.1 VR usage in the Design and Architecture companies

Construction of buildings is affected by the needs of the end-users and social, political and economic factors. The way the buildings are visualized has a powerful significance on designing the built environment. Earlier studies have shown that VR is an appraised new technology that will improve the way design and architecture function in the future (Whyte 2007). Whyte (2007) has stated that new tools of visualization are modifying the practice of design. Bertoll and Foell (1995) have argued that "virtual reality will revolutionize the design of buildings".

Studies have shown that VR is an effective tool for design exploration. The most common way to use VR in architecture is to experience and walk in the non-existing building before it is built (Abdelhameed 2013 & Chan 1997). VR has helped simulating the process of product prototyping and provided an interactive spatial, real-time medium. Virtual reality has been used as a process tool and it has been useful for visualizing the design by linking the reality with the representation (Whyte 2007).

Whyte (2007) found VR to be practical in demonstrating technical competences, design reviews, simulating dynamic operations, coordinating detail designs, scheduling construction and marketing. Demonstrating competence with VR means that an architect or a designer can advertise the skills of the company. It has been marked as one of the major business drivers for VR in the industry. VR in design review means that the designer can improve the design, narrow down the risk of a faulty design and present the design. Marketing helps to sell the products and services. Prospects of the company can experience VR as a part of a proposal, competition entry or a project bid (Whyte 2007, see Fig.12).

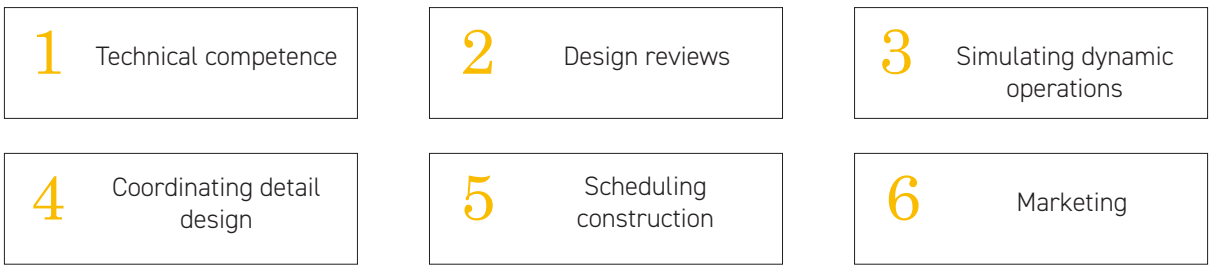


Fig. 12. Benefits of VR in design

(Whyte 2007)

5.1.1 Quantitative data

Data from three studies suggest that VR has been widely used in architectural industry. The quantitative data is based on the surveys carried out during the years 2016 and 2017 by CGarchitect, Sketchfab and Vizpark. The surveys present data on how the respondents view the VR industry, hardware, content and the use and future of VR (Mottle 2016, Sketchfab 2017 & VR AR Survey Results 2017).

A survey by CGarchitect was conducted in June 2016. The survey intent was to present the use of VR in architecture and design companies in 2016 and 2017. The results were based on 376 answers collected through CGarchitect website. The survey by Sketchfab was conducted in the second quarter of 2017. The data was collected through Sketchfab's platform and survey. The Sketchfab platform has 800'000 registered users and the survey was answered by 1600 respondents in the Sketchfab community (VR industry trends 2017). The Vizpark survey was answered by 90 respondents of Vizpark customers in June 2017 (Mottle 2016). Vizpark and CGarchitects service users have worked in the architecture and design industry whereas the registered Sketchfab users have not been defined to belong to any certain industry in particular.

As shown in the Figure 13, the most of architectural visualization with VR takes place in Europe and in the United States (see Fig.13). Most of the respondents were experimenting with the technology or contemplating to do so during the years 2016 and 2017 (see Fig14).

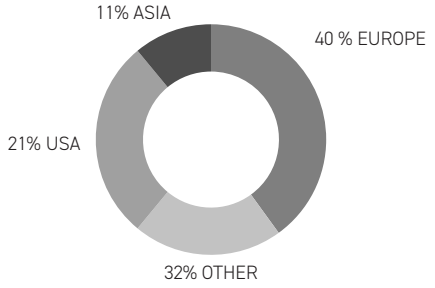


Fig. 13. Where is VR mostly used in architecture and design companies?

(Mottle 2016)

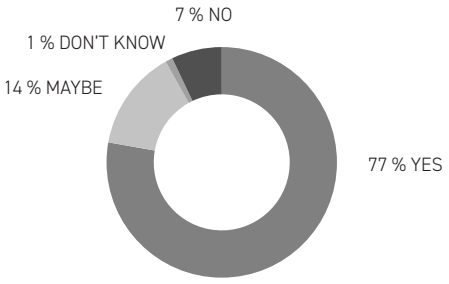


Fig. 14. Are you experimenting with VR in this or during year (2016-2017)?

(Mottle 2016)

69% of those who answered in the survey indicated that they were using VR in the architectural visualization production (see Fig.15). The majority felt that VR will change the way the architecture is visualized partly or completely (see Fig.16). When the participants were asked to share their opinions about VR, the majority of respondents indicated that the technology has potential but it isn't applicable for everything (see Fig.17).The results of these studies indicate that VR is utilized in the design industry and the designers see the value in using the new technology.

Vizpark is creating 3d models and tools for architectural visualization. Vizpark is a technology partner with companies such as Autodesk, Maxon and Chaosgroup. The company helps the partners in testing the products and certifies that the products are compatible with software such as AutoCAD and V-ray. Vizpark has a thousand registered customers around the world and majority of them are 3D artists, architects and smaller studios in the field of architectural visualization. The study was conducted by emailing the questionnaire to their clients (VR AR Survey Results 2017). CGarchitects is an architectural visualization professionals community (Mottle 2016). Sketchfab is a 3D sharing platform, where people can upload and load the immersive VR content (Robertson 2016).

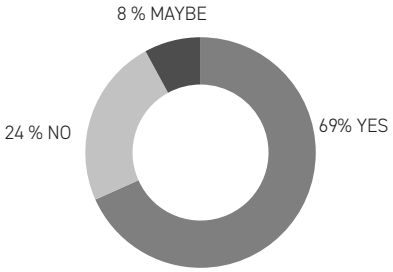


Fig. 15. Are you using VR/AR/MR in production this or next year (2016-2017)?

(Mottle 2016)

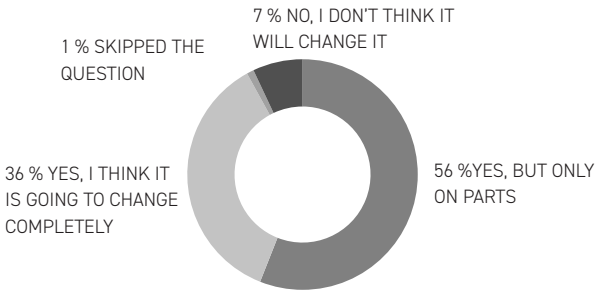


Fig. 16. Will VR and AR change how architecture will be visualized?

(VR AR Survey Results 2017)

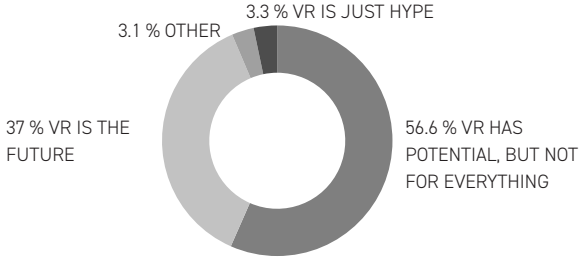


Fig. 17. What is your opinion about VR?

(Virtual industry trends 2017)

These findings may be somewhat limited because the target groups have been technically advanced, possibly belonging to the innovators or early adopters instead of representing the majority of designers. The quantitative study results would have been more interesting if the data was collected from a wider range of participants.

5.1.2 Visualization scenarios

Whyte (2007) identified three main types of model creation in architecture and design studios. In the first scenario, the company has its own central technical department which means that there is a specialist visualization group within the organization which handles all the projects. Most of the organizations that use VR in-house, employ several visualization specialists and the whole staff is not trained to create models. The second scenario is that the visualization is based on projects. In some companies, VR was introduced at the project level but it was not known within the organization and processes were not reusable on other projects. The third scenario is that everything is outsourced. In this case, the organization commissions the creation of the VR model to a service provider either completely or in collaboration with the company (Whyte 2007, see Fig.18). As an example of the outsourcing, ALA Architects outsourced the Oodi Library VR project to Teatime Research (Appendix 4). Whyte (2007) discovered that outsourcing reduced some of the risks whilst leveraging benefits from the VR technologies.

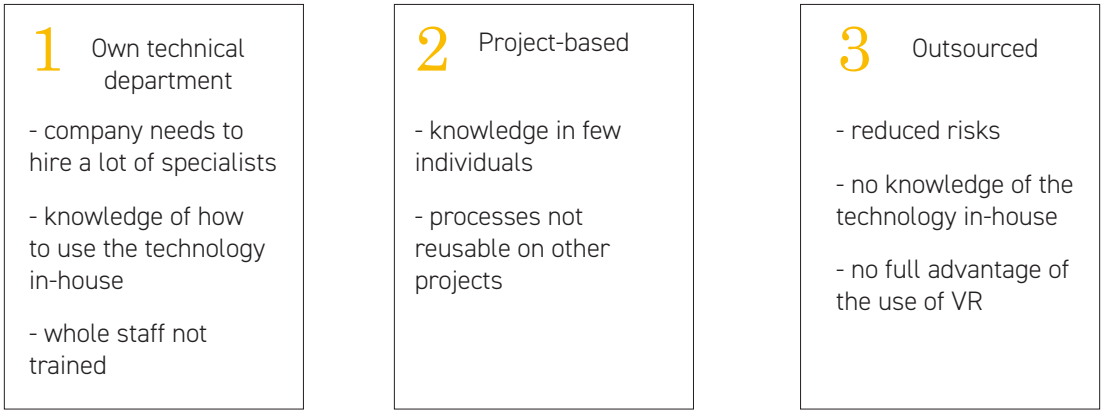


Fig. 18. Model creation in architecture and design studios

(Whyte 2007)

In contrast to Whyte's findings, however, no evidence of the three visualization scenarios was detected. Gensler and TCA Architects have blended the scenarios together (Appendix 1 & 2). This inconsistency may be due to the improvement of the technology. The hardware and software have become easier to use and utilize, which has given the designers more technical independence.

Gensler has implemented a technical department but the company also uses project-based visualization and outsourcing. Genslers' and TCA Architects' specialists have provided the training material for the whole organization, and have taken care that the designers have the right set of tools to work with. In most cases, the designers have created the renderings and VR experiences by following the guidance from the technical team. Sometimes the visualization team has been called to take part in projects that require specialists. For example, Interviewee A participated in the Nvidia headquarter project in San Francisco (Appendix 1 & 2).

5.2 VR software requirements in a Design studio

Currently, the driving force for the development of the VR software is in the entertainment industry (Jerald 2016). However, the development of the design tool applications for architects and designers have started to get more attention among the software developers (How Reality Technology is Being Used in Design 2017). Whyte (2007) argued that designers are aspiring to get more technically sophisticated tools that help them to create interactive, spatial and real-time experiences in VR and there has been a demand for tools that allow the designers to tell the story of the design and focus the clients' attention on relevant issues (Whyte 2007). This data is consistent with data obtained in the thesis study (Appendix 1, 2 & 5).

Organizations have needed to consider ways to integrate VR within the current toolset. VR has not replaced the traditional technique methods such as scale models or sketching. The design studios have been experimenting with VR to discover how VR can best serve them as a new media. Whyte (2007) has claimed that there is a need to present perspective views of conceptual models alongside virtual and physical representations. The designers have wanted to find structured ways of using virtual reality as a tool to support design aims and narratives (Whyte 2007).

Hale and Stanney (2017) listed the general usability requirements for a good VR software; ease of learning, ease of use, user comfort and affordability. Ease of learning means that a novice user can understand and start to practice a technique. Ease of use is referring to the simplicity of the application from the user's standpoint. User comfort means that the user doesn't feel fatigue or motion sickness. Affordability describes the usability, as what technique is to be used for and how it is to be used. The performance requirements for the new technique are speed, accuracy and precision (Hale & Stanney 2017, see Fig.19). The interviewed companies have been pushing to find software that fill the general usability requirements and allow the designers to have a low entry barrier to VR (Appendix 1 & 2).

Fig. 19. General usability requirements

(Hale & Stanney 2017)

Whyte (2007) has claimed that sometimes several different combinations of software is needed to get the desired result. Gensler has taken the same approach. The company has tried to make the adoption process simpler with focusing on a wide range of tools and applications. The large toolset has helped the designers to deliver the presentations and meet the needs of the client. Gensler has used Revit, Sketchup, Rhino and 3D Studio Max for modeling software. The company's primary rendering engine has been V-Ray. Gensler has integrated V-Ray across the applications. It has allowed designers to do ray-tracing rendering at any time of the project taking only an hour of rendering time with the help of Gensler's' rendering farm. Gensler has used multiple applications for VR such as Enscape, Fuzor, Insight VR, Iris VR, Yulio, Substance Designer, Deadline and Clever (Appendix 1).

For high-quality renderings, Gensler has used a ray trace engine like V-Ray. The high-quality renderings have been used for more important and special design reviews (Appendix 1). For very important meetings, competitions or marketing, the company has used outsourced rendering companies (Appendix 5).

Gensler has been pushing to create their own applications and VR software. The company has created a handheld VR application for smartphones and tablets called Gensler application. It has allowed the clients to see the latest VR renderings of their project (Appendix 1). Gensler's designers have used the app as a personalized marketing and development tool for clients (Pacheco 2016). The company has started to hire more software developers to make their own platforms and tools (Appendix 1).

TCA Architects has taken a different approach in implementing VR design software in the company's work flow. The organization has wanted to keep the necessary software toolset and process simple for the designers. Therefore Fuzor has been the only used VR software in the company. TCA uses AutoCAD, Sketchup and Revit for modeling, and Lumion as their rendering software (Appendix 2).

5.2.1 VR Software and game engines

Enscape, IrisVR and Yulio allow the designers to quickly explore the design in VR. These simpler and streamlined but still impressive VR experiences can be uploaded directly from Revit or Sketchup models. (Appendix 1 & Kilkelly 2017). Enscape license costs $400 a year (Appendix 2) and it translates the model into a game-engine like environment that the user can see through a headset like Oculus Rift or Vive. The designer can visit a virtual space where they can maneuver and walk around the design. Enscape offers a quick way to get the designers idea across. The visual fidelity is good for the quick purpose (Appendix 1) and some of the designers have turned from Fuzor to Enscape or other rendering software for better illustrations. Fuzors features are more multi-dimensional, however the cartoonish style is not appealing a large group of designers (Appendix 5).

Fuzor is a VR software that enables the designer to bring the design in VR. Fuzor has multiple features such as clash analysis, lighting analysis, cross section and section cut rendering, color and visibility filters and walk-through video rendering. It supports various measurements (Fuzor BIM Solution 2016).

Fuzor provides a scaling tool that allows to scale the model from the size of a matchbox to a skyscraper. The software allows the designers to place the new building to its upcoming location in the virtual world by using Google Earth. Fuzor helps to ensure that the building is following the participatory design guidelines by letting the designer test the accessibility of the virtual building with a wheelchair. The possible problem areas become visible and the designer can fix them before the manufacturing (Appendix 2). Fuzor helps to add animated scale people and cars with the design in the virtual environment (Appendix 5).

Fuzor can be used as a construction management tool. The construction company can plan all the stages of the construction in detail. For example the construction company can plan the use of construction machinery on the site by creating the different phases of the building process in VR (Appendix 5).

Gensler has used Fuzor mainly because it provides collaborative VR. Multiple designers or clients have explored the VR space together even if they have been located in different countries. Fuzor is bi-directional software that interacts with Revit. All the changes that the designer makes in Fuzor VR will appear in the design drawings in Revit (Appendix 1). The software saves time from the designer because the design changes are made during the meeting with the client (Appendix 2).

The regular software license for Fuzor costs around $4000 a year. The collaborative Fuzor license costs $10'000 a year. Interviewee B has argued that the price of the software is relatively inexpensive compared to how useful and helpful it has been for TCA Architects (Appendix 2).

Models made for marketing purposes are fully immersive VR environments. These VR experiences are made with using Unity or Unreal with the highest rendering quality. This makes them expensive to build (Appendix 2). Fully interactive VR environments require custom programming which can be enabled in a game-engine such as Unity or Unreal (Kilkelly 2017). Gensler has used both game-engines for creating fully interactive experiences but emphasized Unity in the development. One reason for this has been that Gensler has worked with Augmented reality projects with HoloLens which is supported by Unity. The second reason is that Unity has proven to be simpler in developing applications because Unity uses the C# programming language whereas Unreal requires C++ programming language (Appendix 1). Vizpark's survey revealed the opposite. Most of the respondents preferred to use Unreal engine for architecture visualization and only 16% of respondents used Unity as a game-engine (see Fig.20).

The VR models that are used for marketing differ from the models that are used in the design process. Erickson claimed that if the model is very polished, it is more likely that it is used as PR because its' function is to persuade the client to accept the design choices (Whyte 2007). TCA Architects has used a marketing model unit that is a fully interactive high-resolution VR experience. The user has been given options to change the time of day, color scheme, materials and certain surfaces in an apartment. The potential inhabitant has been able to visit the VR apartment from their own living room and make the design decisions from the options that the designer has chosen for them. The marketing demos are usually made in the end of the design process when there are limited amount of design options. Embedding a new set of options in the model takes time because the new marketing VR demo needs to be modeled and rendered (Appendix 2).

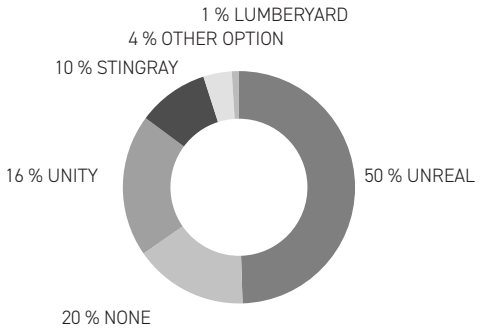


Fig. 20. What game-engine do you use with VR?

(VR AR Survey Results 2017)

Teatime Research has created VR demos for companies in the architecture and design industry. Architect companies have build the model and decided the possible material selections. Teatime Research has taken the built model and changed it with the use of Unity into a fully integrated VR model that the architects' client has been able to tour (Appendix 4).

5.2.2 Working with software developers

Software developers have been working with architecture companies to streamline the adoption of the technology. Working with the software suppliers has helped to reduce the software problems and upgraded the applications with the necessary qualities and features (Whyte 2007).

CannonDesign has advised Enscape to improve the software features and has gained an early access to Enscape's Revit plug-in. (Kilkelly 2017). Gensler and TCA Architects have advised the software developer to improve Fuzors user interface and toolsets (Appendix 1 & 2).

The mutual work between the developer and the design company has benefited both parties. It has helped to unfold new solutions for the software and the design company has gained competitive edge by learning to use the software earlier than its competitors. The positive "symbiosis" has improved the features and qualities and helped the designer to work more efficiently (Appendix 1 & 2).

5.3 Sales and Marketing tool

Marketing is a major driver for the use of VR. It helps to close the sale and deliver product information (Hale & Stanney 2017). VR has been used in architecture to promote sales on both small speculative projects and on larger developments. A major benefit in VR is that it is not tied to a location. Web-based models of hotels, airports and malls can be visited remotely from anywhere in the world (Whyte 2007).

In Japan, house-builders Sekisui House has used VR as one of the marketing mediums. The clients of Sekisui House have made decisions of the quality, floor plans, interior and exterior of their new house. All the made decisions have been combined to a CAD package and taken to VR. In the end of the decision process client has stepped inside their new house in VR. VR has given a platform where the customer and the sales representative have continued the conversation (Whyte 2007).

VR has been used to promote the technological capabilities of the company (Whyte 2007). The new competence has given a reason to contact existing clients, display new services and promote an improved design process (Appendix 2).

VR has been successful as a mean to reach potential clients (Hale & Stanney 2017). Promoting the technological capabilities can happen through media, panels and participating in public discussion. Gensler and TCA Architects have taken part in conventions, panels and events to promote and present the works of the organization (Appendix 1 & 2).

Gensler and their client Nvidia have presented their latest innovations in Siggraph 2017 by displaying the design process of Nvidia's new headquarter. The headquarter has been designed by Gensler and it is built in San Francisco. The whole design and construction process has utilized VR and Nvidia has used the material in their marketing. Nvidia's products such as graphic cards and portable VR was introduced to the convention visitors in the Siggraph 2017 exhibition. The promotion material showed how the headquarters was developed and VR's a major role in the project (Siggraph 2017). VR was a new medium to show the product and market the company and it presented both Nvidia's and Gensler's technological capabilities. This observation supports the hypothesis that VR has been seen as a useful tool for the clients.

5.4 New market with VR

The VR industry has grown its sales every year. Investing the resources to develop skills and the knowledge of the staff may bring more clients and work (Appendix 5). VR has raised the organizations profile by improving the client participation in design and making the company's technical competence more visible. This has made it possible to increase the organizations profit margins (Whyte 2007). Companies have utilized VR to differentiate their products and services or to exploit new markets for spatial design skills (Whyte 2007) such as designing virtual content.

Designing virtual spaces is moving the attention away from the built environment. Cyberspace or networked VR environments allow architects and designers to theorize and create new architectures in an entirely new kind of realm. Architects and designers are presented with new market opportunities in creating virtual content and can change over the concerns related to the built environment in creating content for games, websites and virtual environments (Whyte 2007). Bertoll and Foell (1997) have anticipated that design of virtual worlds will be a new field of interest for the architectural practice.

The interviewed professionals have altered their careers because the new technology has created more possibilities in the field of design. The designers have found job opportunities in creating immersive alternative realities and worlds that don't necessary require building.

The designers have moved their attention to media-rich environments and virtual representations as an option for physical built environment. The virtual realm has enabled the building of virtual cities, spatial concepts and provided a new understanding of a space (Whyte 2007). Bertoll and Foell (1995) have expected that virtual architecture becomes open-ended or endless, something that is morphed by one's fantasies and desires. Hobson (2014) has forecasted that the city of tomorrow will have both a physical and a digital side where people can crossover from virtual space to physical one. Hobson has argued that creating virtual and augmented experiences will be designers and developers focus of work in the coming years (Hobson 2014).

The combination of a physical and digital world has been used in the amusement parks for several years. Disney Imagineering has reinforced their rides with virtual, media-rich environments in the Disney amusement parks. Using VR in the design process has helped to create more vivid and enjoyable fun rides. VR has saved in the costs by allowing to review the ride before construction. The managers have assessed the design before it is built and determined if more changes are required to make the ride more enjoyable (Appendix 6).

Film industry has started to use VR for the same purpose. Interviewee I has participated in the making of a film "Ready Player One" which has been designed with the help of VR. VR has helped the designers to plan the sets, camera movements and filming beforehand. The movie is directed by Steven Spielberg and based in a best-seller book that describes a utopia. In the utopia, VR has replaced most of the everyday tasks. The main character lives mostly in the virtual world, goes to virtual school and knows his best friends only by their virtual avatars (Appendix 6). The environment for the movie has needed to be designed by artists and designers who understand spatial experiences.

3rd Eye Studios, a Finnish game studio has developed story-driven VR games, where the player can interact with a realistic looking virtual environment. The Interviewee D and E have wanted to concentrate in creating games in VR because the technology and equipment have started to be ready for the consumer market. The entrepreneurs realized that VR provided a platform for the customer market when the demo called "Rocket Lab" by Valve was released. The developers saw the new market potential of VR. They founded the company and started to make VR games because the idea of creating the rules and best practices for VR games was intriguing (Appendix 3).

These findings may help us to understand how much potential VR has brought to the industry and how it has changed the job market for the designers. Further work is required to establish the viability of the new market. To develop a full picture of the possibilities that VR has brought for the designers, additional studies will be needed.

6

VR IN DESIGN PHASES

Image 6. (Bismarck 2017).

6

VR IN DESIGN PHASES

This chapter reflects the use of VR throughout the design phases of a design project.

A great amount of design cycles and modifications are inevitable until a final design is established. A design concept is often difficult to conceptualize and communicate among multidisciplinary groups of people. It is possible to reduce the number and duration of the design cycles when problems are visualized and determined at a very early stage of the design process (Kulkarni, Kosse, Kapoor & Iyer 2009). VR will make it possible to express and construct ideas that have been hard to communicate. Design studios and architectural organizations that use VR in their design phases have been very effective (Chan 1997). The next chapters will go into detail how the VR can help each design phase. Design phases can be divided in a conceptual design, schematic design, design development, construction documents, construction bidding and construction administration phases (see Fig.21). The thesis has merged the conceptual design and schematic design phases as well as construction bidding and construction administration phases together.

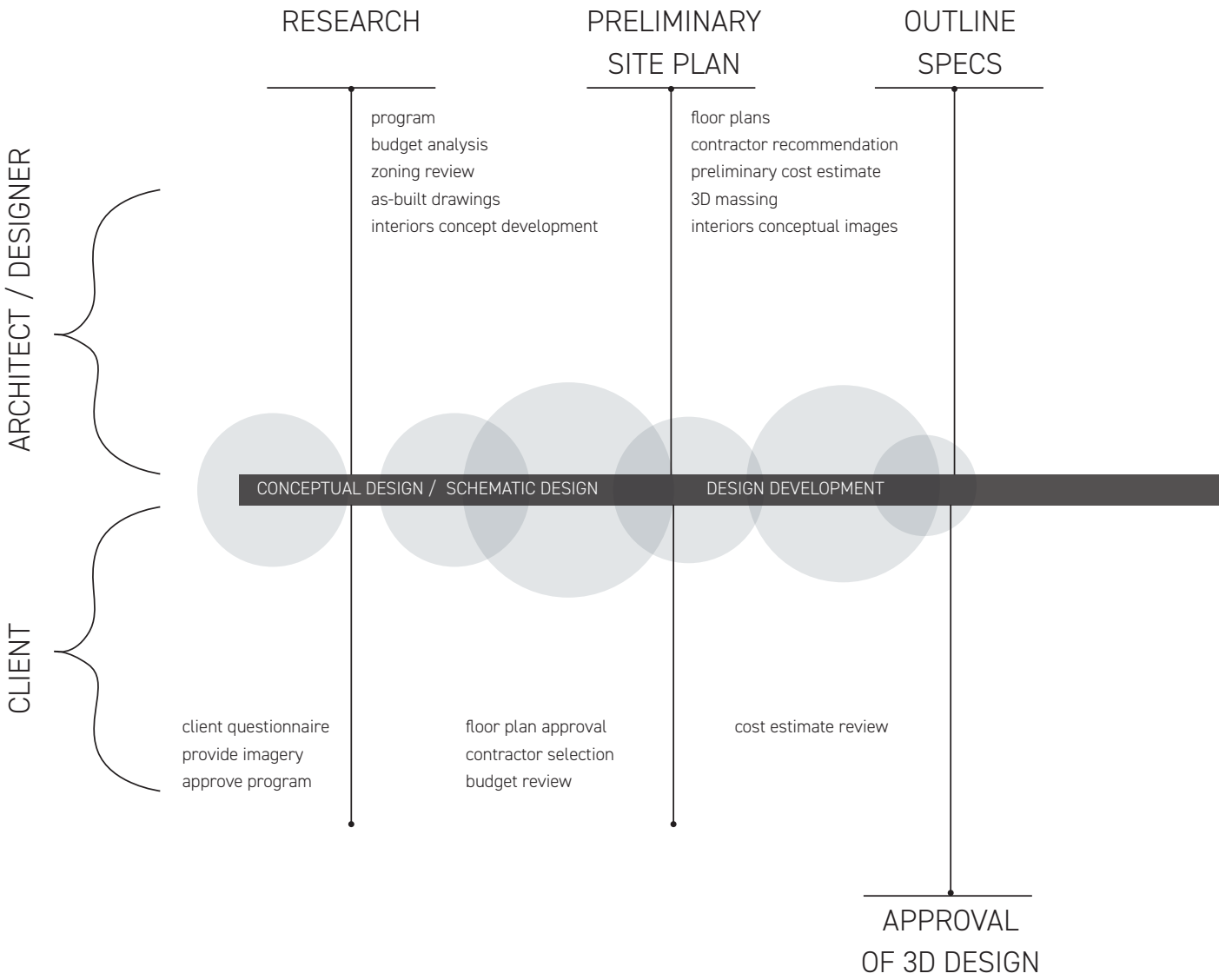
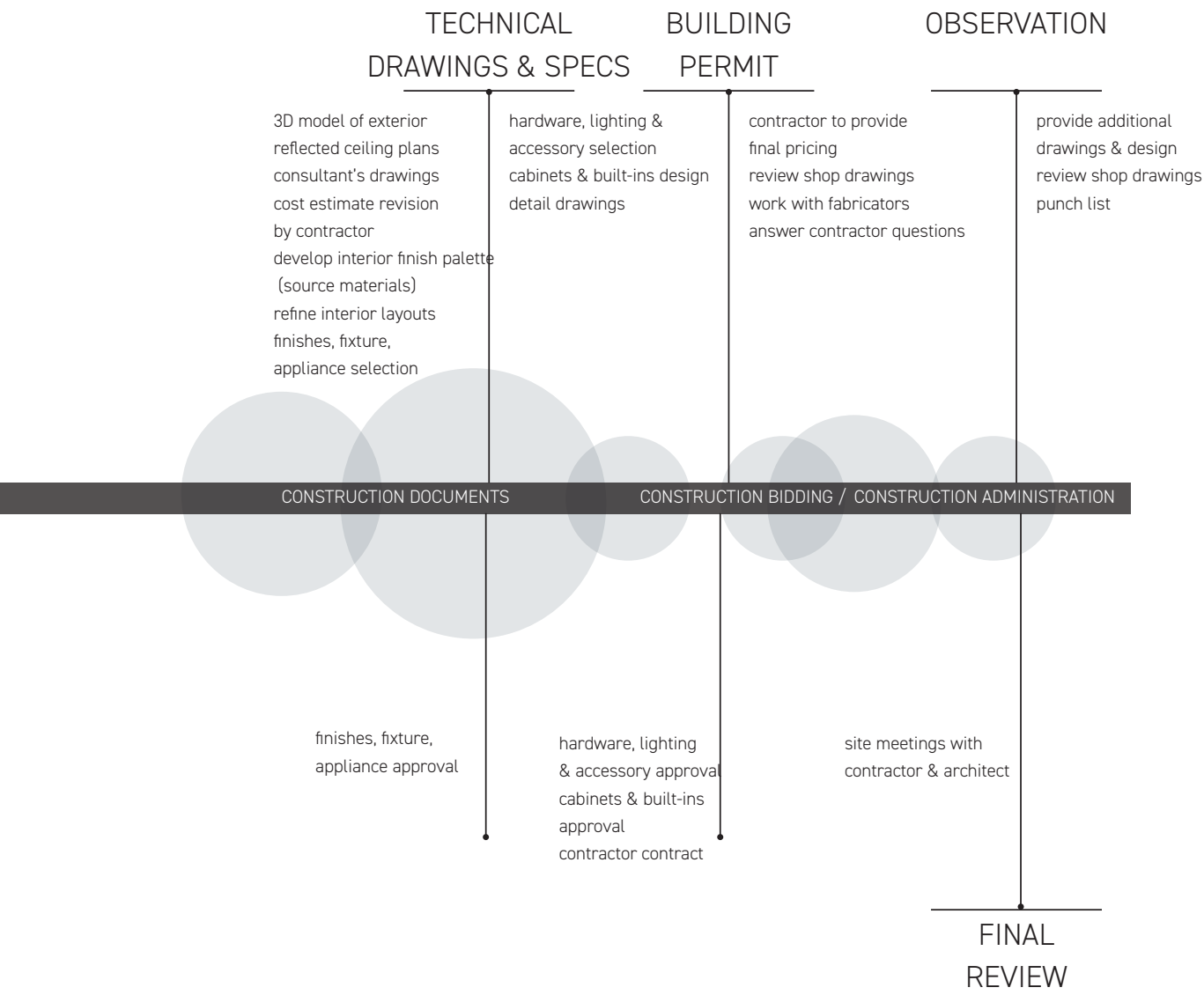


Fig. 21. Design phases

(adapted from Design phases 2017).


TECHNICAL
DRAWINGS & SPECS
BUILDING
PERMIT
OBSERVATION
3D model of exterior
reflected ceiling plans
consultant's drawings
cost estimate revision
by contractor
develop interior finish palette
(source materials)
refine interior layouts
finishes, fixture,
appliance selection
hardware, lighting &
accessory selection
cabinets & built-ins design
detail drawings
contractor to provide
final pricing
review shop drawings
work with fabricators
answer contractor questions
provide additional
drawings & design
review shop drawings
punch list
CONSTRUCTION DOCUMENTS
CONSTRUCTION BIDDING / CONSTRUCTION ADMINISTRATION
finishes, fixture,
appliance approval
hardware, lighting
& accessory approval
cabinets & built-ins
approval
contractor contract
site meetings with
contractor & architect
FINAL
REVIEW

6.1 Conceptual and schematic design phase

Architectural design traditionally begins with an idea. Usually after the idea has been created, the architect has sketched a 2d concept. Pencil-paper medium has been translating architects and designers ideas into physical products for generations (Chan 1997). Sketching and building a physical scale model have supported the ambiguity and fast exploration of possibilities (Gross & Do 1996 as cited in Whyte 2007). Interviewee B has argued that sketching will continue to be used as an early design method (Appendix 2).

Chan (1996) has stated that using only traditional methods of tools in the design process limits the inspiration and the generation of the idea. Chan (1996) has believed that providing diversity during a design process could give an opportunity to improve the design quality and broaden the personal vision, enrich the imagination and stimulate holistic thinking (Chan 1997). Chan (1997) has believed that the computer technology has revolutionized architectural representation. VR has been declared as a "next logical evolution for rendering technologies" (Pacheco 2016).

The results of this study has showed that VR has helped to solve the problems very early in the design phase and benefited the design process further down the line (Appendix 1). In the early phase of the design, architects have sensed spatial relationships and massing of the space by rendering the space in VR at a different level of detail (O'Connell 2016) with simple conceptual forms and limited palettes of colors. The designers have reached an intuitive approach with using solids and voids (Whyte 2007).

Whyte (2007) has argued that the most successful implementations of VR is, when it has been used alongside other means. The architects and designers in Gensler agreed that the physical scale model offers a quicker and more efficient method than the digital one in the concept phase. The physical model can be altered manually whereas the digital model has had to be modified beforehand (Appendix 5).

CO Architects has used VR for discovering the unknowns during the design process. The company has explored a concept model in an immersive environment which has helped the architects and clients to comprehend the design better. VR has enabled the designers to test different options at full-scale model early in the process (Kilkelly 2017).

Gensler has integrated VR as a design tool in the early conceptual stage (Pacheco 2016). VR has helped the designers to evaluate the design in the early phase of the process in which they have been able to look pass the unfinished degree of the design. The designers have seen the value in understanding the massing and relations of the design (Appendix 1). VR has been deployed to convey the design intent as the design process evolves (Pacheco 2016).

In the current study, comparing the results of studios using VR with the design phases figure, it can thus be suggested that one could determine specific tasks in the conceptual design phase that benefit from the use of VR. Figure 21 presents how VR could be integrated in the conceptual design phase. The designers could use VR to develop the interior concept with VR and the client could approve the floor plan exploring it with VR. The preliminary site plan could be taken to VR for design review (see Fig. 22).

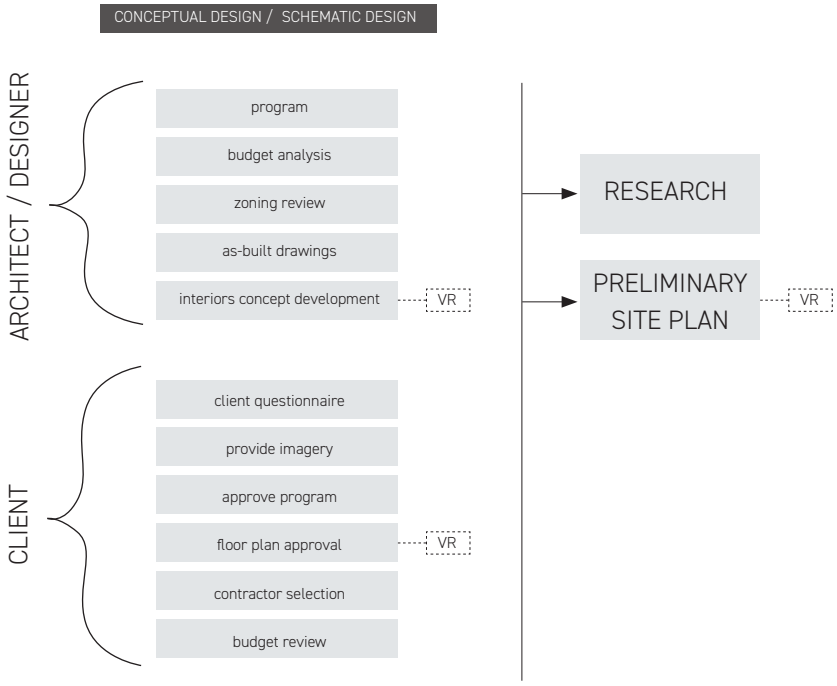


Fig. 22. Conceptual design & schematic desing

(adapted from Design phases 2017).

6.2 Design development phase

Whyte (2007) has elaborated that even though the studies have not defined any correct approach to use VR, virtual reality has been mostly utilized at the later stages of the design process. Virtual reality has been used for problem solving, testing the idea and as a persuasive media to portray the built environment (Whyte 2007).

VR has provided a new tool to present and see the design in a different context which has helped to detect mistakes or possible problem areas in the design (Whyte 2007). VR has enabled the experience of visiting the space before it is built. This has given the designer an opportunity to work on the building to achieve the intended appearance and atmosphere (Appendix 2). VR has saved time, money and effort when designers have detected and corrected a mistake in the design with the help of VR during the design development phase (Appendix 2).

VR has helped the designers to work together and share thoughts in a visual space even at different locations. The designers have performed tasks and added audit trails of comments in the virtual elements of the design (Whyte 2007). Visualizing ideas and giving feedback has happened simultaneously. Net system has collected data and recorded the processed information for later manipulation. The recordings have been used to simulate, plan and visualize the thinking process of the design (Chan 1997).

Virtual reality has benefited the design reviews in big range of project types from custom-made residencies and interiors to large complex buildings. During the client presentations, the architects and designers have represented a design with using a wide range of media. These have contained plans, sections, perspectives, physical models, animations and interactive, spatial and real-time models (Whyte 2007). VR has made it possible to get clients and designers in the same virtual space where a real-time model has been explored and interacted (Pacheco 2016). VR has allowed both clients and architects to understand the spatial qualities of the design (O'Connell 2016) and make design decisions easier (Appendix 1).

The design choices have been shown with using a restricted palette of pre-determined choices in VR. For example, restricted palette options have been used to fine-tune a hospital environment that makes the patients feel most comfortable (Whyte 2007). On the contrary to the restricted palettes, Gensler and TCA Architects have used Revit and Fuzor to explore the design with the client. The modification of the model in Fuzor is not as restricted as in a high-quality VR model in that it allows real-time modification (Appendix 1& 2).

Creating the design alternatives virtually has been less expensive than building several different physical models (Abdelhameed 2013 & Chan 1997). Kulkarni, Kosse, Kapoor and Iyer (2009) have introduced an alternative prototyping analysis called virtual design process (VDP) in which the designers think of ways to make the design samples without manufacturing physical ones. VDP tool has cut down the design time, improved the design quality of the product with validating it at the early stages of the design cycles. Using VDP tool has cut down prototyping costs. Models have acted as input for the detailed design and drafting. Using VDP in the design process has supported collaborative engineering (Kulkarni, Kosse, Kapoor & Iyer 2009).

According to these data, we can infer that the use of VR could benefit the design development phase in creating floor plans, 3D massing and the conceptual images. VR could be used in the review of the 3d design and utilized to persuade the client to accept the design (see Fig. 23).

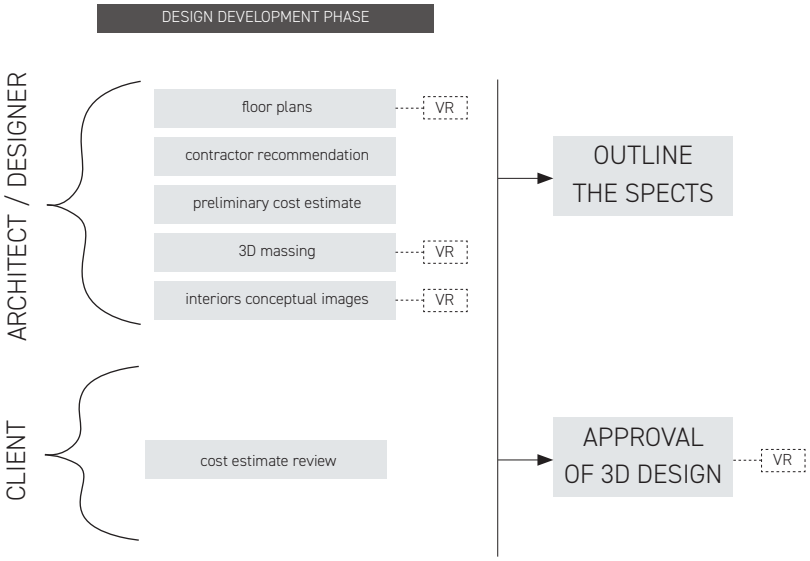


Fig. 23. Design development phase

(adapted from Design phases 2017).

6.3 Construction Documentation phase

The architects and designers have to convey a very complex information in a detailed and clear way so that their design can be constructed. Generally, the architects prepare a construction document by using two-dimensional drawings. The drawings do not present the building the way people normally understand and see the space. VR has bridged that gap (Appendix 2). VR has augmented and extended the CAD packages and given a platform in which various professionals have been able to communicate together (Whyte 2007).

During the construction documentation phase, the use of VR has detected clashes and conflicts in the design. VR has provided a visual analysis of the space. Prototyping designs, considering different alternatives, visualizing available engineering and design data in VR has helped professionals to find faults and clashes earlier. Sometimes VR has been used to explore entirely new solutions (Whyte 2007).

VR has been a good tool to achieve and test the participatory design of the building. Wheelchair tests in VR have obtained data about the potential collision points (Whyte 2007).

Interviewee B has described that TCA Architects design process has flexibility all throughout the whole design process until the construction documentation phase ends. The organization has exercised VR to check the usability and functionality of the design. VR has ensured and verified that the design is matching the vision of the architect (Appendix 2).

In the construction documentation phase, Disney Imagineering Research and Development has simulated their project designs merging the modeling information with scheduling data. The organization has viewed it in real-time, analyzed and used the data to plan the construction project, furthered the physical engineering process, predicted the life cycle costs and possible building performance issues. Disney Imagineering has used VR also for conflict and clash detection (Whyte 2007).

VR has presented architectural drawings, textual data, animations and photogrammetric images in the Zamani Project by the University of Cape Town in which VR has helped to construct the enhanced spatial domain of African heritage (Ford 2017).

These findings suggest that VR could be a major factor in the construction documentation phase. It could be used in almost all of the design tasks excluding tasks of signing the contractor contract and preparing the building permit (see Fig.24).

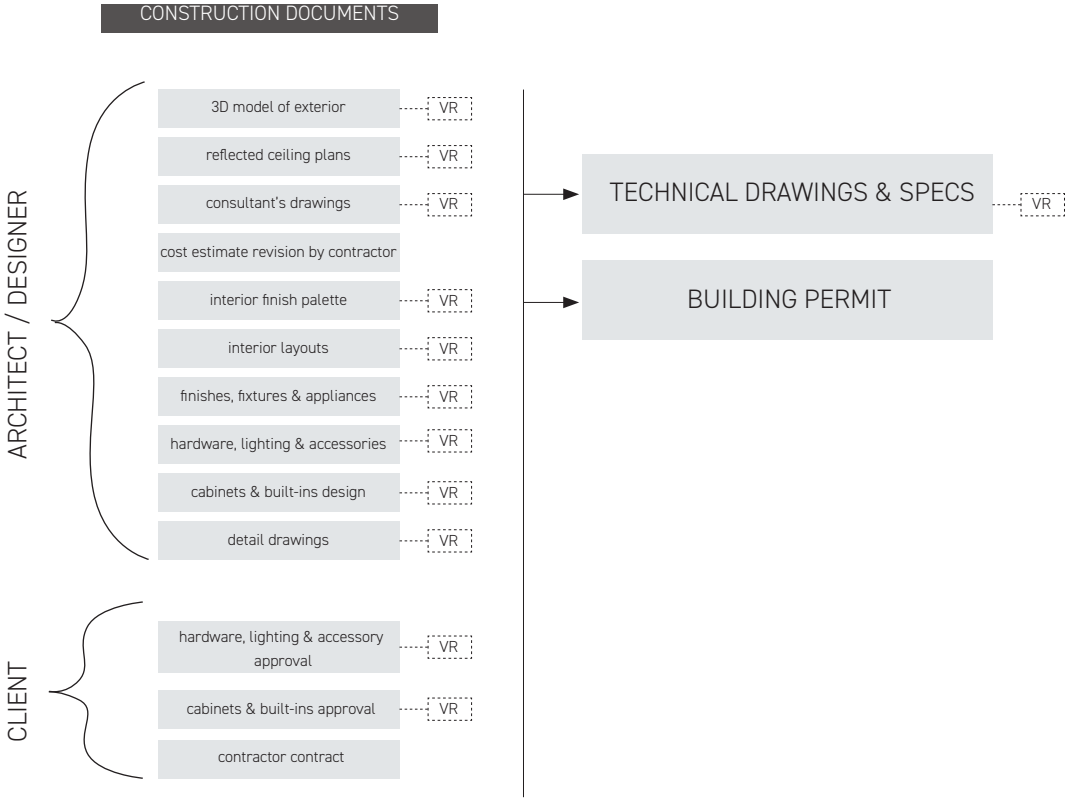


Fig. 24. Construction documents

(adapted from Design phases 2017).

6.4 Construction bidding and Construction Administration phase

Currently many processes within the construction sector haven't depended on previous information as every building has been a unique piece of work without full scale prototypes. VR has offered a solution and a way to prototype the building and its infrastructure before it has been built. During the later design and construction phases, VR has reduced the redesign labor and delays. VR has helped simultaneous engineering processes and improved the quality of the design. Professionals have automated existing processes and educated professional in the project group (Whyte 2007).

Whyte identified four major business drivers in using VR in the construction administration phase such as simulating dynamic operations, speeding up the design implementations, coordinating detail design and scheduling construction beforehand. VR has enabled better exploitation of large buildings and infrastructures, improved processes and reduced risks and costs (see Fig.25).

1. Simulating dynamic operation - to improve product quality and safety of the operations
2. Speeding up the design implementations
3. Co-ordinating detail design - to reduce the cost of errors and redesign work
4. Scheduling construction – to reduce lead time, incompatibilities on site and waste

Fig. 25. Major business drivers in using VR in construction

(Whyte 2007).

VR has provided a tool for architects to revisit the design after the plans for the building have been submitted. If a problem has occurred in the construction site, an architect has found the solution by exploring the VR space instead of having to go through a 300 pages long construction document. VR has expedited and saved money on the construction processes by streamlining the answering to the 'Respond of Information' (RFI's) requests (Appendix 2).

VR has found to be suitable tool for sectors that produce complex systems. Co-ordinating work plans through VR has improved the understanding of various professionals in the project team and VR has been used to discuss between disciplines within multidisciplinary organizations. Facility managers, contractors, property owners and consultant engineers have used VR to visualize and manage complex engineering and design data. As the data has been visualized with all the involved companies, intellectual property rights may arise problems, but the importance of the shared visualization of information has benefited all the parties involved. Value engineering of a project has reduced costs without compromising the design quality (Whyte 2007).

VR has allowed professionals, regulators, clients and consultants to review the design together to secure critical safety matters. VR has been used to inspect the location of equipment and important safety controls such as signaling that could improve the safety of the building (Whyte 2007).

Construction contractors have been made progressively more liable for co-ordination of detailed design. This has motivated the contractors to identify errors early in the building process. VR has helped to detect small differences between the drawings of several professionals that otherwise could have lead to issues in the construction site (Whyte 2007).

In general, therefore, it seems that VR is involved in the majority of construction bidding and administration phase tasks. These results provide further support for the hypothesis of the study that virtual reality is a valuable architectural design tool which improves the efficiency and quality of the design work while also effectively aiding clients, constructors, and fellow designers in understanding the creative vision of design work though all phases of a project (see Fig.25).

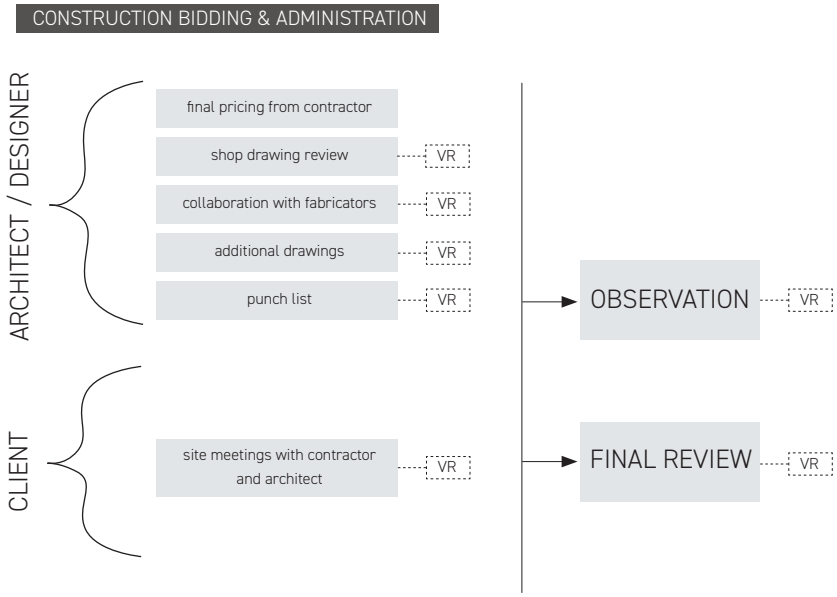


Fig. 26. Construction bidding & administration

(adapted from Design phases 2017).

7

DESIGNERS AND VR

Image 7. (Meyer 2015).

7

DESIGNERS AND VR

This chapter considers the designers work with VR, their opinions about the technology, the development of designers' skills through VR and what challenges and opportunities VR has brought to clients and designers.

7.1 Designers' benefiting from the use of VR

As explained earlier, VR has been a useful tool for design generation, comparing the design alternatives and improving spatial thinking (Furness 1987 as cited in Whyte 2007). VR has streamlined iterative processes and has facilitated the visualization of the design material and large data sets that could be difficult to comprehend with traditional systems (Jerald 2016).

VR has given an opportunity for the designers to self-reflect the design. It has revealed aspects of architectural production beyond the building itself presenting the complex data from multidimensional aspects (Ford 2017). VR has allowed designers to perceive and understand (Chan 1997) the architectural design visually, aurally and interactively (Ellis 1991 as cited in Chan 1997).

VR is believed to be every architects tool in the future (Collins 2016). So far, the designers have been working on a flat 2D screen with a perspective or isometric view of the 3D viewport. Once the designers have been placed inside their own design in VR, it has surprised them by revealing the benefits. VR has helped to make decisions, detect design mistakes and improved the quality of the design (Appendix 1).

Instead of raw imagining, the architects and designers have created the surroundings, spatial qualities and the topological relationship of a building and its environment in the virtual reality (Abdelhameed 2013 & Chan 1997). The architects and designers have comprehended the design by walking through the virtual space visualizing the colors and textures of assigned materials, proportions of the spatial layout, and the aesthetic expressions of structural elements (Chan 1997). Mairs (2016) has found that the designers can use their whole body as tool and evolve the dimensional and the user-friendly relationships of spaces and components. Designers have experienced less limitations in the sequential decision-making processes because of the use of VR (Whyte 2007).

TCA Architects has found that VR has been extremely useful, when a project has been complex and has special design details. Interviewee B has appreciated that VR has helped to detect if the scale of the design is wrong, if the space feels too narrow or the ceiling is too low (Appendix 2). Architects have tested the design with using the perspectives of a child or a tall adult (Appendix 2).

CGarchitect survey has reported that VR has brought potential in the architecture industry and the professionals have been mostly significantly positive. The respondents have believed that VR will revolutionize the industry, be the future of architecture and design and that VR directs the architecture in a new era. The respondents have believed that the technology is now adequate to provide good results. One respondent has been excited about how VR is improving the communication with clients and has believed that clients will be expecting the architecture industry to use VR and AR in their client presentations (Mottle 2016).

7.2 Designers communicating with clients

Gensler and TCA Architects have noticed that a portion of the clients have struggled to envision the design intent from the 3d plans and renderings (Appendix 1 & Appendix 2). VR has provided a platform that shows the design from a normal viewing perspective (Appendix 2). Virtual reality has solved the communication problem between the architects and clients (Appendix 1). Gensler architects have believed that VR has helped drastically the communication process with the client (Appendix 5).

The designers of Hickok Cole Architects have realized how VR has changed the communication with the client. The architects used VR to highlight unresolved issues in the design of International Spy Museum. When the designers shared the VR model with the client, they couldn't carefully curate styled views of the project as they could with conventional 3D renderings. The client explored the model however they saw fit and paid attention to details that the designers hadn't considered important. The realization helped the designers to understand the client's priorities, intents and the actual use of space. The designers discovered which areas would be more used in the building by tracking the clients' movements in VR (Kilkelly 2017).

When TCA Architects started to use VR, they contemplated of charging VR services separately on top of the project billing. The first initiative changed rapidly because architects realized that VR was beneficial to the designers as well as their clients when VR was integrated as a part of the project. VR offered value for the client and gave TCA a competitive edge. The clients understood that VR was a helpful tool and saw its benefits. VR progressed the project onwards faster because the communication between the client and the designers was easier. VR was more valuable and delivered better feedback than diagrams, emails and several meetings (Appendix 2).

CO Architects discovered that the VR experiences need to be focused and brief. Five to ten minutes long reviews with VR have been the most efficient (Kilkelly 2016). Panoramic views have allowed the architect to pick key locations for viewing the digital building (Whyte 2007). VR has been best shown at the end of the presentation. VR can sidetrack and derail the conversation if design review has been started with exploring the design in VR. All the important information should be communicated with the client beforehand that designers have discussed the needed topics with the client before going in the virtual environment (Appendix 1).

7.2.1 Decision making

Understanding of the space has given more confidence for clients to do the design decisions which has saved time spent in meetings and design revisions (O'Connell 2016). Interviewee B has compared the VR design reviews to a test run (Appendix 2). Providing the testing of a product has given the client certainty and built trust between the architect and the client (Appendix 1 & 2).

VR has worked as an insurance for the client. Clients have invested a great deal of time and money in a construction of a building. VR has shown them where their money is spent. VR is a guarantee against the capital and proof that the building is a good investment. Professionals have provided more security for the project with the use of VR and saved money in terms of time, change orders and issues of construction and design (Appendix 2).

Gensler has been able to realize how accurately VR visualizes the architecture projects now that the projects are starting to come to completion. The building and its interiors have looked exactly the way they have been shown in VR (Appendix 1).

Gensler has noticed that showing even one simple and conceptual VR rendering to the client has conserved time. VR has helped to communicate the design and to receive immediate feedback. Clients have made savings on the architecture fee when they have spent less time in making the decisions (Appendix 1). For example, Gensler worked on a restaurant design project in which the client couldn't approve the design because they couldn't understand the architects' vision. The client had seen a lot of Sketchup renderings but he didn't understand the design until it was experienced in VR. The client agreed to go through with the plan after the VR experience (Appendix 1).

Los Angeles Football Club stadium design project was one of the best cases for Gensler to understand how useful VR is as a decision making tool (Appendix 1). During the design process of Los Angeles Football club, the designers and clients struggled to decide where the LED scoreboard should go in the stadium. Placing the score board in the station was a very difficult decision using the floor plan and renderings. The LED Scoreboard needed to be visible to everyone in the audience. By the time Gensler decided to use VR, the client had seen several different presentations but hadn't been able to decide the location. Gensler rendered different options where the scoreboard could go and showed the client all the options in VR. The rendered VR options helped to make the decision in 10 minutes. VR provided the necessary information for the client that the client was able to make one of the biggest design decisions in the project (Appendix 1).

VR has saved costs and streamlined the decision making process in hospitality projects at Gensler. The common practice in hospitality projects has been to design the hotel room and build the entire hotel room in a warehouse as an example version of the space. The client has seen the space and given comments of the choices. With the help of VR, Gensler has replaced the physical models to virtual ones. The model has obtained all the design options and the client has made the needed decisions of the color schemes and the furniture. After the decisions have been made, Gensler has built the physical room. Because the tactile feel of the hotel room is important, the final physical prototype of the room needs to be built. However, choosing the furniture and certain color schemes and finishes has saved a lot of valuable time and costs (Appendix 1).

VR has been used to persuade the client to make a certain design option. Whyte has argued that the client has often chosen better but more expensive design option when they have seen the quality difference between the proposals (Whyte 2007).

7.2.2 Participatory design

Whyte has argued that virtual reality may be the most useful when testing the design and discussing about the design solutions. Design reviews can be used to involve clients by a participatory design approach (Whyte 2007). VR has facilitated a place for clients, managers and end-users to understand the design, contribute their experience and explore the space. VR has been used to gain strategic information and knowledge from how the clients, managers and end-users inhabit the space. This has allowed the designers and clients to discuss the design issues, make the required changes in the building and enhance the quality of the final product (Whyte 2007).

ALA Architects and the city of Helsinki reviewed the design of the new central library Oodi with VR. Teatime research provided the software solutions for the architects. This allowed the designers to discover how the space was used by the visitors and the librarians. The librarians tested the ideal relations and distances between spaces and functions (Appendix 4).

NBBJ's Seattle office developed a tool with a startup company called Visual Vocal that streamlines the collaborative design process by letting the clients access the design of the project. The firm referred the tool as a "breakthrough virtual reality productivity platform". McConnell claimed that the partnership has radically shifted the way design feedback has been sourced and then integrated into projects. The platform streamlined the gathering process and the users were more broadly and deeply engaged in the design. VR deepened the design discourse and brought communities together in a new way (Pacheco 2016).

The designers and architects of Dubai International Airport used VR to check if the internal and external signage was used in a structured and instructive manner. The airports security personnel walked through the model and proposed design changes from a security point of view (Whyte 2007). CannonDesigns clients have trained their staff how to use the forthcoming facility before they move in (Kilkelly 2017).

CO has used VR to mock-up complex labs and healthcare spaces. The company has allowed doctors and nurses to virtually work in the space, test its layout and scale before the spaces have been constructed. All the projects in CO have applied VR in different capacities. The staff in CO has noticed that everyone can relate to VR even if they don't know how to read drawings (Kilkelly 2017).

7.3 Learning professional design skills

VR has become a valuable visual tool for the architectural learning and teaching (Chan 1997). The interactive nature of VR has made it an excellent teaching tool. Users have understood the spatial qualities of the design immediately, comprehended the major components of the HVAC system, visualized the colors and textures of the materials, experienced the proportion of the space as well as understood the aesthetics and structures of the elements (Chan 1997). VR has provided a safe learning environment that could otherwise be dangerous (Jerald 2016). Users have experienced spaces and scenarios or tested hypothesis. Users that have interacted with new information have been more likely to remember the knowledge afterwards (Abdelhameed 2013).

VR has made a good tool for education because it is engaging, fun and a new way of learning that has little resemblance to school. Sullivan et al. (2011) claimed that VR learning is more appealing and enjoyable than other educational mediums that offer the equivalent content (Hale & Stanney 2017). The advantage in learning with VR is that absurd or dangerous experiences can be simulated without costly or serious consequences. VR can replicate field trips and architectural walks (Fiore, Harrison, Hughes & Rustrom as cited in Hale & Stanney 2017). The virtual environments are safe to excursion. (Hale Kelly & Stanney 2017). VR has a unique affordance for developing a spatial knowledge (Dalgano & Lee 2010 as cited in Hale & Stanney 2017). Learning complex concept and ideas is enforced with combining interactive simulations (Lindgen & Swartz 2009 as cited in Hale & Stanney 2017) and spatial perspectives can be manipulated in a way that has enhanced knowledge. (Luo, Luo, Wickens, & Chen, 2010 as cited in Hale & Stanney 2017).

As mentioned, VR has offered an excellent learning platform for exploration. The user can control an avatar that has free reign to walk or fly through the world. (Hale & Stanney 2017). User can visit environments that have not been physically accessible such as the Bronze Age environment that the British Museum developed in 2015. Although there is a great potential to facilitate learning with VR, matching the experience of the extremely nuanced real world can be very challenging. Adding multiple people into the learning space only increases the complexity (Hale & Stanney 2017).

Gensler's VR Jam has been a weekly occasion and it usually has been participated around 20-30 designers. The VR Jam has started in LA and Newport offices and has grown to 22 offices. Almost half of the company have had a possibility to join the weekly VR session where architects can learn from each other and share a lot of detailed and complex information from the projects (Appendix 1).

7.4 Designers doubts about VR

Regardless of the excitement, Whyte (2007) noticed that not all designers and architects welcome virtual reality. Some of the architects were worried that VR restricts the creativity and use of imagination (Whyte 2007). Adopting new technologies has brought benefits, but it has also created difficulties and challenges (Hale & Stanney 2017). Virtual Industry Trends (2017) claimed that the negative opinions about VR systems were related to costs, content and the technology (see Fig.27). These results are consistent with the thesis study. Most comments about the challenges in VR were related to the use of VR, software, equipment, navigation, organizational problems and motion sickness (Appendix 1,3,4&5).

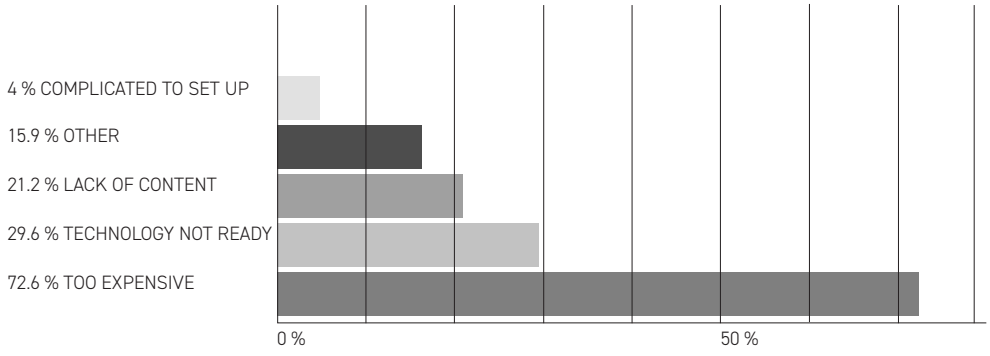


Fig. 27. Why haven't you bought a VR headset?

(Virtual Industry Trends 2017).

72.6 percent didn't buy the VR headset because they feel that the equipment is too expensive. 30 percent of the respondents believed that the technology is not ready and 21 percent thought that there is not enough content for it. 4 percent of respondents argued that VR is too difficult to set up and 16 percent had another reason such as an incompatibility with prescription glasses, not wanting to buy a VR compatible computer or having access to the technology through a university or a workplace (see Fig.27).

Future threats and uncertainty

Architecture is changing due to VR. The architects at Gensler have had a lot of questions related to the role of the designer and what is going to happen to designers when the technology will make the designing of the buildings more accessible to other professionals. Will VR take a lot of jobs away from the architects? Could VR decrease the appreciation of the profession? The uncertainty of the future has caused agitation (Appendix 5).

VR could possibly open the architecture industry for developers who are experts in the making content for the virtual spaces. The designers were concerned that video game developers can start to compete with architecture companies with developing concept designs. Clients could start to question the design costs and the skill set of architecture companies. In worst case scenario, clients could turn to video game developers and engineers to do the design for buildings and spaces. One architect argued that there has always been both good and bad design no matter what the means and tools are available. Architects and designers' duty is to keep up with the changes in the industry and develop skills to grow professionally. Architects and designers must learn the VR software and technology to stay current so that they are able to compete from the jobs in the architecture and virtual content field (Appendix 5).

Interviewee B forecasted that the change of the design industry has already started and if the architects and designers have not started to adopt VR, they are falling behind. Interviewee B compared the situation with the events that took place in 2005-2006 when Revit was adopted by the architecture industry. Architects lost projects if they didn't use Revit. Interviewee B believed that the same events will happen with VR. Integrating the VR technology in the design processes, companies can stay profitable (Appendix 2).

Control of the design

Architects and designers have not been able to control easily the design review and what the client has explored in VR. The clients have accessed spaces that have not yet been designed. This has set a requirement that everything has needed to be thought out in VR (Appendix 5).

The designers and architects have needed to decide, how much participatory design they have wanted to include in the project. There hasn't been a simple fix to involve the users. One concern has been that VR might not provide a right kind of balance of control and participation. VR can lead to a situation where the designers don't have a right balance of control and participation when showing the design to their clients (Whyte 2007).

VR usually increases participation but it can also reduce it. Clients are not likely to share their opinions if they notice that all the decisions have been made for them (Whyte 2007). Using highly realistic renderings may impress clients, but they might take attention away from the relevant issues and make the design look inflexible. Client reviews are best used to question the design choices rather than seduce the client (Whyte 2007) unless the meeting is about marketing and showing the technological knowhow of the organization. If the designer has left out all the real possibilities to give feedback or comment the design choices, the clients are less comfortable to give their opinions (Whyte 2007).

Showing "too" much

Educating the clients has been an important part of the adoption of VR. The architects have needed to explain that the design is work-in-progress and open for changes, even though VR shows a 360 view of the design (Appendix 5). Whyte (2007) suggested that communicating with the client through VR is done conservatively that the immersive experience doesn't deliver a wrong impression of the design especially in the early stages. The VR model has to look polished but at the same time it should give a message that the design is not finished. Showing too much can put the architects in a situation where an unfinished design study is misunderstood as a ready design (Appendix 5).

Lack of time

VR has saved a lot of time which has improved the design process. However, some architects have felt that working without VR has provided more design exploration time because VR has shown everything in the design. When the design is premature and not developed enough, the attribute of VR as enhancing the understanding of the client is working against the designer. Using VR in the beginning of the design process has also shifted the expectations for the next design review. Architects have felt that they would require more time to deliver a great design. Managing to meet the clients expectations has created pressure in the design process (Appendix 5).

VR requires expert skills. Fully integrated VR rely on game engines and those have a whole different work flow than architecture software. The learning of the software is time-consuming. Architects found it hard to acquire time to test and experiment with VR and the new applications (O'Connell 2017). VR AR Survey respondents confirmed this and listed the lack of time in learning the software, as well as working on the projects as a concern (VR AR Survey 2017).

Software

VR could be used more if the tools and the software became more sophisticated and polished (Appendix 5). The VR AR Survey measured the features that the respondents missed in their work flow while working with VR or AR. Several answers related to an integration of software's, getting an easier work flow and having a better conversion between the modeling software and the real-time engine. One concern was, that the clients didn't know what the restrictions of the software are (VR AR Survey Results 2017) which creates misunderstanding in the deliverables.

The problems with software could be tackled if Unity and Unreal develop VR solutions geared towards architecture and design such as Autodesk Live and Stingray that maintain building information when importing the BIM data in VR. Gaming software hasn't captured the iterating project and construction information, because the focus in gaming systems is largely on generating idealized VR experiences (O'Connell 2017).

Equipment

Users are opposed of wearing bulky VR equipment and the blindfolded user can easily stumble with the loose wires. Using of the head-mounted display is awkward and prevents the users to fully endorse the technology (Appendix 5). TCA architects has had a trouble convincing some of their clients to try VR because the heavy head-mounted displays. Clients who have hold the display with their hands on their faces have blocked the sensors and the VR system hasn't been tracking the head movements (Appendix 2).

Distorted reality

In virtual reality the designer creates alternative and compensatory realities, that give a polished and intoxicated version of the reality. The built model is a twisted image of the built environment. VR won't be able to show the building as precisely as in reality. Because it is a simulation, unattractive aspects are left out and unnoticed aspects are not added in the experience. The technology is still detached and insulated from reality (Whyte 2007).

Overwhelming the user

Performing tasks in VR has become increasingly difficult when more information is added. Participants of a VR experiment have failed to filter out non-essential information and haven't been able to carry out the necessary tasks (Goerger et al 1998 as cited in Whyte 1997). Novice users have had a hard time to focus on the designers' voice when they have first put in the VR environment (Appendix 4).

Many clients are novice users of VR and has been crucial that they don't feel incompetent or frustrated in exploring in VR (Whyte 2007). Teatime research has noticed that people tend to be flustered if they have observed too much information all at once. The instructions of how to use and move in the environment have needed to be simple and easy (Appendix 4).

Navigation

Novice users have had difficulties when navigating in VR. Differences between virtual and real environment have affected navigation and way-finding (Satalich 1995 as cited in Whyte 1997). Users could become disoriented, bump into virtual objects, veer off course and take considerable amount of effort from the task-specific objectives. (Darken and Sibert 1993 as cited in Whyte 2007).

Organizational problems

Version control problems are likely to happen in the company if the organization has distributed information data without structure. Whyte (2007) has commented that organizational problems have been stressed in numerous case studies. To get the value of the technology, VR should be used to communicate processes and share tasks through VR that contain information (Whyte 2007).

Architects and designers won't use VR if they can't see the benefits of the technology. Professionals can be concerned that VR is used to weaken their position and won't take advantage of the software (Whyte 2007). Communicating the rules, new work flows and the value of the new technology, will create structure, educate the staff and motivate the employees to perform better with new design tools.

In order to use VR efficiently alongside the other means, various questions have needed to be answered. The adoption of VR has been based on trial and error because the designers have needed to create best practices, organizational rules and guidelines for the use of VR. The designers have needed to think ways to induct VR to the scheduling, design phases, deadlines and project management and communicate the changes with the clients (Appendix 5).

VR can drain resources if it is used inefficiently. There is a danger that VR is used to treasure the prototypes and enhance the model too far. Shrage (2000) has described that when people often want to add features in a successfully demonstrated model, it might just end up like a Christmas tree.

Economic factors

One architect has argued that the unique projects haven't allowed the reuse of the VR models and there has no been any benefit from the economies of scope. Architects have been less confidence that VR could help the organizations economically. Architects felt that they would get inadequate business gain from using VR for design review (Whyte 2007). On the contrary, recent research has suggested that all the architects in the study see the value and market potential in VR (Appendix 5).

VR has brought the question of how to bill the service and how can the architecture companies make more revenue in using the VR. There has not been an easy answer to how to bill a client for VR. CannonDesign has decided not to bill clients for VR services such as walkthroughs or virtual tours because they are an extension of the design process. The firm has seen the interactive VR mock-ups as an additional billable service and will charge a fee for this type of work (Kilkelly 2017).

Motion sickness

One of the adoption challenges of VR is the unresolved issues with physical ergonomics. Lawson (2014) argued that cybersickness and related syndromes are significant obstacles when it comes to wide spreading the use of VR technology (Hale & Stanney 2017). Many organizations have been reluctant to make commitments to technologies that clearly has caused nausea to portions of their staff and clients (Hale & Stanney 2017).

There are two instances where motion sickness happens in VR. Motion sickness occurs when the virtual environment is moving and the user is standing still. The brain knows that the body is not moving which creates a disjointed experience. VR animations and videos can cause motion sickness unless the user realizes that they are sitting down and the environment is moving around them. Users are likely to feel motion sickness, if someone else is controlling and moving the user in VR. The other reason for motion sickness is that the hardware doesn't meet the required frame rate (Appendix 1). The recommended frame rate is 90 frames per second per eye and for a lot of people even 60-70 frames per second is acceptable. If the frame rate drops below 30, the motion sickness occurs. Gensler has been extra careful in presenting their designs for their clients with VR because the designers want to give the client the best possible experience. Interviewee A has stated that "It's better not to have VR than to have VR and make the CEO of a company sick" (Appendix 1).

Some users have felt motion sickness more than others (Appendix 1). To prevent the motion sickness, the architects can encourage the users to go slow and check in on them frequently. CO Architects has prioritized their VR experiences in user comfort because they have noticed that there is a concern among the clients that the sensation of moving in a virtual space causes motion sickness (Kilkelly 2016). The 360 renderings with a gear VR or Google Cardboard can be an answer for people who experience motion sickness because they are static images and the users can't really move around in it (Appendix 1).

High-resolution VR model are more attractive compared to VR experiences in Enscape or Fuzor. Fully immersive experiences demand more from the computer, which can cause the image to stutter and give you a poor VR experience. Fuzor is not looking as beautiful as a high-resolution model but the experience is smooth and will reduce the possibility of motion sickness (Appendix 2).

Setting up the VR equipment needs to be done carefully so that the users movement in real life are representing the movement in the virtual environment. If the set up is not done correctly, the users movements are not correctly imitated in the virtual world and the user can feel motion sickness (Appendix 3).

Greenwood-Ericksen, Kennedy and Stafford (2014) claimed that VR applications have been the broadest and most successful in entertainment (Hale & Stanney 2017), but if the users experience dizziness, the experience might not be successful for long. Disney Corporation explored the advantages of VR with its fun rides such as Aladdin VR ride. 5-10% of Aladdin visitors experienced motion sickness after riding the fun ride. This can interfere the appeal for VR systems (Boman 1995 as cited in Hale & Stanney 2017).

Space requirement

VR has required a reasonably large area for moving and that normal consumers or small boutique design companies might not have, which has created new challenges for VR developers to think about ways to move within the virtual environment (Appendix 3).

8

VR CONTENT

Image 8. (Thomson 2015).

8

VR CONTENT

This chapter describes the concept, storyboarding and content creation in an architecture studio.

8.1 Storyboarding

In the beginning of the design process, the architects and designers attempt to understand the needs of the client. The interpretation is formed into a concept. The concept is then comprised into a story that is used to communicate client presentations and design reviews (Appendix 2). Whyte (2007) emphasized the importance of telling a carefully choreographed story to the client when describing the design.

The planning of the story has been defined as storyboarding. The storyboarding process has been used to discover how to match the requirements of the clients and what factors should be limited and added in the experience. The process has helped to ensure that the experience has matched closely to the requirements of the client (Hale & Stanney 2017). Gensler has done storyboarding for the client in 2D medium, PowerPoint and PDF style presentations and has currently started to do the storyboarding with VR (Appendix 1).

VR has required new methods for telling the story (Appendix 1). Usually a storyboard for films has been made using frames of pictures and description of the experience, however the storyboarding of VR has been different because the client has seen 360 degree view of the environment (Hale & Stanney 2017). The architect has needed to invent ways to turn the clients focus on certain areas. Gensler has begun to learn more techniques to storyboard in VR (Appendix 1). The next section of this paper addresses attributes the designer should consider in creating a VR experience for design reviews.

8.2 Content attributes

Virtual reality can't exist without content. An engaging content includes a conceptual arc of the story, the design of the environment and computer or user-controlled characters, audio and visual highlighting (Jerald 2016). As mentioned in the Chapter 7, using VR can cause inconvenience and discomfort. The designer can try to make the VR design reviews more convenient by focusing in the content requirements. The human visual system creates requirements for a certain fidelity such as field of view, colors and brightness. To get a smooth and natural visual experience without image flicker, frame rate should be a minimum of 60 Hz mono, 100 Hz stereo (Hale & Stanney 2017). Frame rate 90 gives an immersive VR experience but even 60-70 is a competent frame rate that doesn't cause motion sickness issues (Appendix 1).

In addition to the human visual requirements, Hale and Stanney (2017) identified four spatial requirements for the content design; spatial orientation, information gathering, engagement and enjoyment. The spatial orientation means that the users knows the lay-out of a space and their own position within it. This has been especially important in large and complex buildings. The information gathering means that VR shares the needed information of the environment. The engagement means the involvement of the user with the virtual environment. Hale and Stanney claimed that the enjoyment is the most important requirement and an indication of success (see Fig.28). The enjoyment as the most important aspect may be explained by the fact that Hale and Stanney are referring to all of the VR experiences including designing game environments. Concentrating in enjoyment may be secondary for the architectural design reviews but should not be forgotten in creating the content.

Fig. 28. Spatial requirements

(Hale & Stanney 2017).

In addition to Hale & Stanney, Stuart (1996) argued that VR experience should deliver these nine variables; sociability, veridicality, resolution, immersion presence, engagement, reconfigurability, responsiveness, stability and robustness (Stuart 1996 as cited in Hale & Stanney 2017, see Fig.29).

1. Sociability: to permit multiple users to share an environment
2. Veridicality: the accuracy of the modeled environment (fidelity)
3. Resolution: the level of precision and details
4. Immersion presence: users experience
5. Engagement: how deeply the users are involved and occupied with what they are doing
6. Reconfigurability: the capability to modify a model
7. Responsiveness: the ability of a VR to respond to inputs
8. Stability: lack of jitter or oscillation in the display
9. Robustness: the ability to function correctly

Fig. 29. Nine variables of a VR experience

(Hale & Stanney 2017).

Professional project team		Wider involvement
Abstract		(Photo) realistic
Symbolic		Iconic
Engineering system		Surfaces
Exocentric viewing perspective	VS	Egocentric viewing perspective
Rapid design changes in real-time		Fine-tuning of design office
Design aids		Navigation aids
Free-viewing		Controlled viewing

Fig. 30. Attributes for the project team vs for wider involvement

(Whyte 2007).

The models for wider involvement such as final presentations and marketing are designed differently than the models that are used by the design team. Whyte listed attributes emphasized in models for use by the professional project team and models for wider involvement (see Fig.30).

8.3 Creating content for VR design reviews

Hale & Stanney argued that the storyboarding helps in deciding the shape and form of the virtual environment (Hale & Stanney 2017). In order to communicate the story, the designer will need to make design decisions (Hale & Stanney 2017) regarding the visualization of the VR experience used in the design reviews. Simplistic wireframe communicates different qualities of the design than a smoothly shaded highly realistic model (Whyte 2007).

The designer can choose if the representation of the users body is showing the users limbs, full body or none of the body. This affects how the user understands what they are doing, where they are and what possibilities and interaction there is in the virtual environment (Hale & Stanney 2017). The designer can use sound, shadowing or the complexity of the pictorial realism to enhance the understanding of the environment (Schatz & Chertoff, 2013 in Hale & Stanney 2017). The designer can choose to provide interface support such as mixed-reality design, metaphors or interface elements (Hale & Stanney 2017). At TCA Architects the design reviews have included the use of realistic topography from the site. For example, VR has presented the context through Google Earth VR or shown the scenery of the clients' new high-rise in New York in VR (Appendix 2).

The designer can support navigation and orientation with interface tools, aids, shortcuts and routes (Darken & Peterson 2014 as cited in Hale & Stanney 2017). Creating highly navigable virtual worlds is familiar with game designers. Game designers have given a player a feeling of an open environment when in fact the environment has been structured and a linear experience where you cannot free-roam everywhere (Hale & Stanney 2017). Designers could benefit from learning from game designers to improve their skills in designing VR experiences for clients.

The founders of Teatime Research have argued that creating an interactive VR model requires time. The model needs to be tested well to ensure that the application is easy to use and the user can intuitively know how to navigate the space. Testing decreases the chance of causing awkwardness or embarrassment for the user (Appendix 4).

The designers can decide the appearance of the scale model avatars and where to use them (Hale & Stanney 2017). Concerns were expressed about the use of the avatars. Interviewee B elaborated that the architects first avoided using the avatars because they startled the users (Appendix 2). Gensler's clients have been distracted by the computer-controlled avatars. The designers have usually left the avatars white so that the clients wouldn't focus their attention to them. The designers argued that appearance of the 3D avatars has not been developed enough (Appendix 1).

Despite of the problems with using the avatars, TCA Architects has used animated avatars and cars in their VR models to show the scale (Appendix 2). Showing the movement of people in a retail center in the VR scenes has added more depth to the experience and could help to sell the project to the client (Appendix 1).

Gensler has wanted to use AI in their VR experiences to show the movements of the crowds in their models. However, the company has not yet found an application that is mature enough to test Egress or provide accurate data. Autodesk has started to create simulators for crowds in terms of how Egress works (Appendix 1).

Using sound in VR has not yet been a high priority in architecture companies. However, there is an interest to add it in the VR experience. Gensler has noticed that the sound hardware and the licenses of sound effects and music have been expensive. The sound producing companies have started to create game licenses and interactive licenses because of the new medium (Appendix 1).

3rd Eye studious has realized that sound plays a huge role in the immersion of VR. Interviewee D and E from the video games company have believed that sound could benefit design reviews in architecture industry (Appendix 3). TCA Architects hadn't experimented with sound yet but believed that the sound makes the experience better. TCA Architects has planned to set up a surround system instead of earphones in the VR space. The simplicity of the wearable equipment makes it easier to convince clients to try VR (Appendix 2).

Gensler has been looking to integrate Nvidia's new software VR works in their VR models. Currently stereo and the headphones have created a fake surround sound of the surrounding environment. VR works has a tools and plug-ins to help the performance of VR. The new audio tool is using Nvidia's ray tracing technology for sound. The tool calculates the way the sound bounces off the surfaces, materials and walls such as the ray. This creates believable sound effects for VR (Appendix 1).

Architectural model file size has been usually large and created challenges for the computer to process. More sophisticated and realistic form of rendering has required more computational time (Whyte 2007). More computational time can be resolved with rendering farms. Gensler has used rendering farms to expedite the rendering process (Appendix 1).

The design reviews with VR have offered a way to introduce the new building to the client as the way the user would enter the premises naturally. TCA Architects has used a leasing walk for apartment building projects. The leasing walk has described the route from the parking lot into the lobby, through the leasing office and first amenity space, to the pool and finally into the apartment. The walk has helped the client to experience the natural way of navigating in the space (Appendix 2).

9

FUTURE OF VR

Image 9. (Howarth 2015).

9

FUTURE OF VR

This chapter explains how VR relates to potential revenue growth, employment, collaboration and design methods in the design and architecture field and how the development of the equipment affects it.

3rd Eye Studios has forecasted that the future of VR will change how people work, communicate and learn. Interviewee D and E have predicted that VR could provide a training tool for students and professionals (Appendix 3). VR could change functions in education, sales and marketing, entertainment, social aspects, medical and manufacturing industries (Appendix 4). Mixed reality has been said to become more important technology in the future (Appendix 3 & 4).

The majority of Sketchfab's survey respondents believed that gaming industry will be the most impacted industry by VR in the next five years. 18.1% of respondents acknowledged that education and health will be affected by VR. 10.9% of the respondents answered adult industry, construction, art and advertising (see Fig.31).

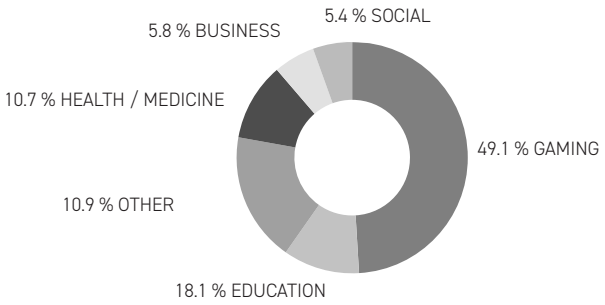


Fig. 31. What industry will be most impacted by VR in the next 5 years?

(VR AR Survey Results 2017).

9.1 Revenue

According to the International Data Corporation (IDC), the worldwide revenue for virtual and augmented reality was $5.2 billion in 2016 and will grow to $11.4 billion in 2017. The corporation forecasted that the worldwide revenue will be $162 billion in 2020 and $215 billion in 2021. If the forecast holds up, the annual growth rate will be 181.3% over the 2015-2020 period (Chute & Shirer 2016 and 2017, see Fig.32).

Asia, Pacific, United States and Western Europe will be accountable of 75 % of AR and VR global revenues. The forecast speculated that United states revenue will bypass Europe and Asia and Pacific regions by 2020 (Chute & Shirer 2016 and 2017).

IDC is a global data provider that offers global expertise on technology and industry opportunities and trends with 1,100 analysts worldwide. IDC's analysis helps executives and professionals to make fact-based decisions (Chute & Shirer 2016 and 2017).

These results differ from Super data's estimate for the revenue in 2020. Super data is a data and market research provider focused on intelligence in the digital games market and interactive media landscape. Super data has forecasted the worldwide revenue of virtual reality industry to be $37.7 billion in 2020 (see Fig.33). This inconsistency in the forecasts may be explained by the fact that augmented reality industry revenue is missing from the Super data forecast. However, the fact might not explain the difference completely. These forecasts therefore need to be interpreted with caution.

Accurate data of how many VR headsets have been sold until today has not been released. HTC Vive and Oculus Rift haven't published their sales information. Super data evaluated that 6.3 million devices were sold and the industry revenue was $1.8 billion in 2016 (see Fig.34). IDC evaluated that 10 million AR and VR headsets were shipped globally in 2016 and forecasted that the number will grow to 100 million in 2021 (Hamblen 2017).

VR & AR revenue forecast by IDC (Chute & Shirer 2017)

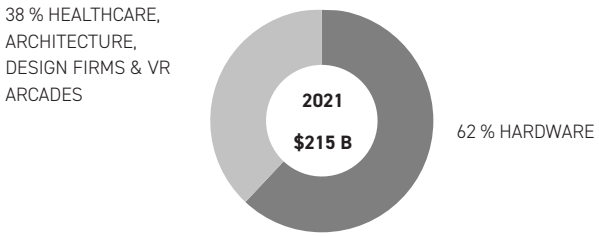


Fig. 32. VR & AR revenue forecast by IDC

(Chute & Shirer 2017)

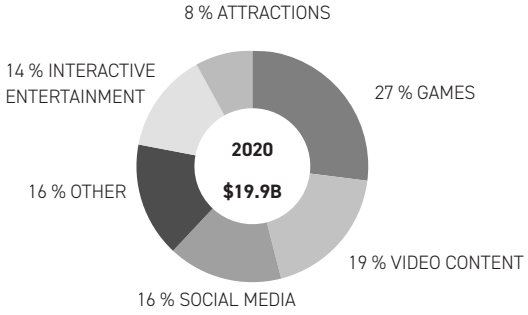


Fig. 33. VR Software market segment forecast by Super data

(Games and interactive media intelligence 2017).

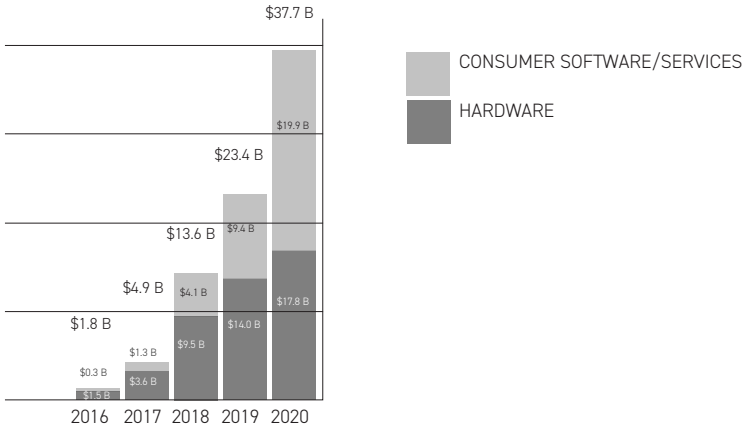


Fig. 34. Worldwide VR revenue by Super data

(Games and interactive media intelligence 2017).

Super data divided the total revenue to two parts, consumer software and services and hardware and that in 2020 the software and services will be accountable for 53% of the total revenue (see Fig.34). Super data divided services into consumer software segments; games, video content, social media, interactive entertainment, attractions and other (Games and interactive media intelligence 2017). IDC predicted that in 2021 services such as healthcare, architecture, design firms and VR arcades would comprise 38% of the market, leaving 62% for the hardware (Hamblen 2017). Even though, the amounts of the percentage in the forecasts differ, it can be assumed that architects and designers will benefit for the adoption of the VR in the future.

This combination of the forecasts provide support for the conceptual premise that the plausible adoption of the critical mass will have a positive effect on the future revenue of the architecture industry. However, as mentioned earlier, many factors affect the adoption of the technology. There are several challenges in the use of VR that the industry needs to solve before the mass adoption happens.

9.2 Employment

VR is finding its home in design and in enterprise level areas (Appendix 1). Interviewee B has forecasted that the adoption of VR will disrupt the industry in next few years. If a company is a laggard (see Chapter 4) in adopting the technology, the competitors can outrun them with technological capabilities and win over the prospects. Interviewee B has argued that the adoption process will cause several companies to make mistakes and lose jobs, but others who have integrated VR will thrive (Appendix 2).

VR has involved several academic disciplines and professional specializations (Jerald 2016). This makes the architectural world more open to professionals working with VR. It may open possibilities for other professionals to orientate to the architecture industry (Appendix 5) and create more competition for jobs. Although, at the same time, more possibilities have opened up to designers because of VR (Appendix 3, 4 & 5).

Several questions remain unanswered at present at how the employment will be affected by VR. Future studies on the current topic are therefore recommended.

9.4 Technology

Hale and Stanney (2017) believed that lightweight goggle-based VR displays become widespread and substantially inexpensive in the next decade. Hale and Stanney (2017) suspected that the boundaries of the virtual environment and the physical world will get fuzzier and the elements of the VR co-mingle with objects and landmarks of the real-world. Immerse displays could overlay important facts and other material on top of the real world that the user is watching through the goggles (Hale & Stanney 2017).

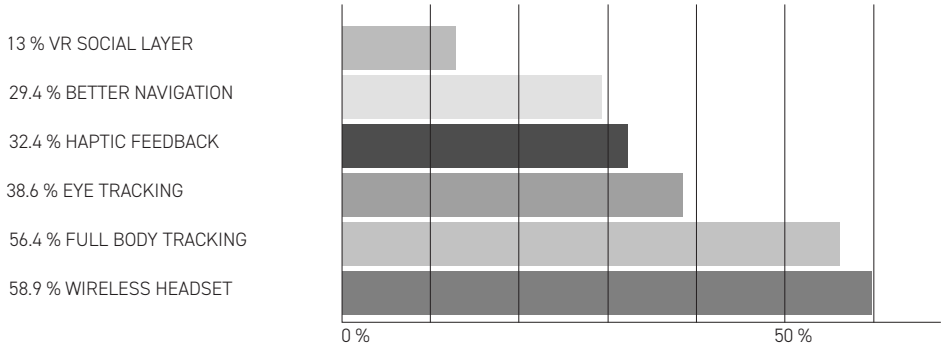


Fig. 35. Which future feature(s) are you most intrigued?

(Virtual Industry Trends 2017)

Interviewee B argued that the users want the VR experience to be more immersive, more detailed, higher quality and be able to render larger models, but at the same time hardware and software needs to perform faster and the equipment needs to become lighter. Technology companies are focusing on developing more mobile equipment and VR software that is more straightforward and simpler to use (Appendix 2). When asked the most intriguing future feature of VR, the respondents answered the wireless headset which allows the user to walk in the VR space more freely (see Fig.35). A wireless headset has been introduced to the public in Siggraph 2017 by Nvidia (Siggraph 2017). Oculus Rifts wireless headset will be published to developers in 2018 (Matney 2017). A wireless VR headset saves a lot of time and energy in the set up and gives more freedom in the use of VR.

VR developers are working on creating a multi-sensory environment that reaches for more nuanced haptic experience, where your body could touch, smell and hear (Ford 2017). Lawton argued that the stereographic technologies such as more advanced multi-view displays and light-field techniques continue to mature. These technologies would allow the user to experience VR without glasses (Lawton 2011 as cited in Hale & Stanney 2017). Hale and Stanney have predicted that the more sophisticated design of graphics engines and accessibility kits push the development to more immersive and physically interactive VR experiences and make VR more mainstream (Hale & Stanney 2017).

The quicker architects and designers adopt VR, the more they shape the future marketplace. Architects and designers should vision the huge opportunities and synergies in the design world. The designers should communicate with VR developers that they realize the possibilities beyond gaming and consumer markets. This collaboration would lead to better tools and software that is required for designers to excel (O'Connell 2016).

Skolnik claimed that VR technology hasn't advanced yet to its full potential The designers and developers as content creators can push the industry now to go to the direction that is the most beneficial to them. When the goals for the development are identified, it is a matter of time when the technology will reach the objectives. The more the designers and developers can push for these changes, the more useful tool VR will be for them in the future (Upload VR Event 2017).

9.3 Collaboration

Interviewee A expected that the next big buzzword in VR will be the collaboration (Appendix 1). Working together efficiently in teams can be practiced in VR with a sophisticated, coordinated and effective action (Hale & Stanney 2017).

Kilkelly argued that architecture industry has mostly seen isolated VR systems that don't enable multiuser VR in which architects could lead architectural tours to clients (Kilkelly 2016). Interviewee B confirmed that VR has been currently solitary experience at TCA Architects, however collaborative VR is currently in the market and the company has been testing with it (Appendix 2). Gensler has used collaborative VR in their VR Jams, however, the experience has not yet allowed simultaneous changing of the surroundings (Appendix 5).

Fuzor has provided a service where architects can create an environment and share an access code that will allow clients to visit the same virtual space. Clients can either free-roam in the space or be guided by the architect (Appendix 2).

Nvidia showed their collaborative technology demo in Siggraph 2017. The demo presented a VR car design application where the users collaborated, changed the materials and colors of the car, wrote comments or notes in the screen and communicated with other users. The tool showed promise for the client reviews and for collaborative VR (Siggraph 2017).

Williams & Kirschner (2012) believed that collaborative systems and environments will be substantially changing the learning in VR. Professionals could use VR as a learning platform and learn various methods, processes and principles in various design cultures (Chan 1997).

9.5 Design

Chan argued that VR could change the way the design industry communicates and thinks. If the designers shared their project information online, the data could be used and accessed from anywhere in the world. Clients and other designers could access the visualizations and provide feedback instantly. This could break the convention and improve the design profession by developing an interactive and intermediate environment (Chan 1997). VR has the potential to alter how architects design and how clients experience and review the concepts (Kilkelly 2017).

Ford (2017) argued that architects haven't yet fully exploited VR's possibilities. Designers have not leveraged the technological advances to reorient the conversation during the design or documentation phases to describe the complexities of the buildings. Architects could present the facts of the demographic context of the site, the design solution in relation to its ecology along a temporal dimension, the economic impacts, the cultural landscape and the site's history. This information could be beneficial for recognizing and sharing with the clients and colleagues. VR could host this type of multifaceted approach (Ford 2017).

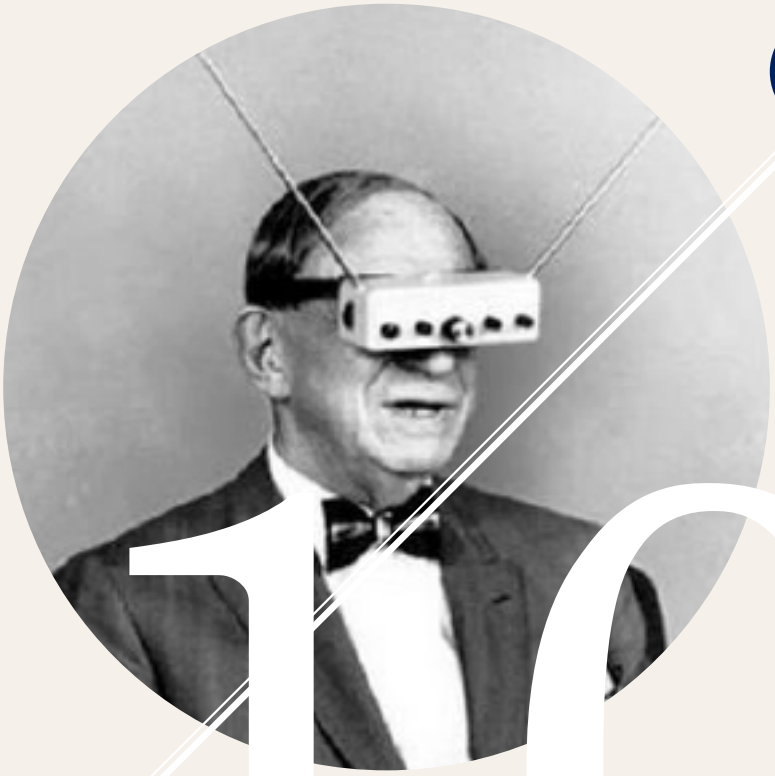
Mairs believed that designing within the virtual reality and stepping directly inside the space and intuitively building spaces in real world scale helps the design process in numerous ways (Mairs 2016). Interviewee A believed that designing in VR will become a reality in the future with modeling applications such as VR Rhino and Sketchup (Appendix 1). Interviewee B questioned the designing within VR, because the current manner accommodates precision and is convenient and rapid. Interviewee B thought that designing in VR won't be possible in the near future. Building a model takes less time and effort with a regular modeling program than being in that space and controlling the surrounding masses. There are startup companies that are creating software for this purpose, however Interviewee B hasn't yet seen any application that has shown promise (Appendix 2).

An important aspect of designing the product or building has been validating the need for it (Kulkarni, Kosse, Kapoor & Iyer 2009). According to Kulkarni, Kosse, Kapoor and Iyer (2009) creating a tool for scale prototypes has reduced time and money. It saves material that could otherwise be used to build the prototype (Kulkarni, Kosse, Kapoor & Iyer 2009).

If the designed space can exists in a virtual world and give the same experience as a physical version, there is no need to use scarce resources of material to build it. Therefore, VR could create solutions for excessive consuming and help to use construction materials intelligently. There is need for further research in determining if VR could be used to prevent overconsumption.

These findings raise intriguing questions regarding the nature and extent of the advancement of the VR technology. If the technology can be experienced without VR headset, one could even suggest that the concept of VR could disappear. The reality could become a combination of material and imagination. In this scenario, the position of a designer would be intriguing, because the creations of this new reality would need to be implemented. This future vision is similar to Hobsons (2014) predictions mentioned in Chapter 5. Hobson has argued that creating virtual and augmented experiences will be designers and developers focus of work in the coming years (Hobson 2014).

CREATIVE PROJECT



10

CREATIVE PROCESS

Image 10. (Ackerman 2016).

10

CREATIVE PROCESS

This chapter describes the creative project and design phases of three modular homes. The design phase presentations shown in the thesis do not include all the detailed information and images due to usage rights.

The creative project of the thesis has been designed for a company called MinunLOFT. MinunLOFT is manufacturing houses using a construction method that combines steel structured framing with polyurethane insulation. The benefits of the method are clean indoor air, cost-efficiency, speed of building and durability. The company has presented their first steel structured house in Mikkeli housing fair 2017, which has been was designed by architects Kaija and Petri Eerikäinen and the interior was designed by Anita Koponen (MinunLOFT 2017).

The design brief from the company has been to design a house that can be prefabricated using 3.5 meter wide modules, polyurethane insulation and a steel structure. The standard height for each room should be 3,5 meters minimum. The design process has started in October 2016.

The demands of the client have evolved during the process and, as a result, the creative process has generated three modular loft home models, client brochures and marketing material. The first MinunLOFT house renderings have been published in the housing fair in Mikkeli in the Summer 2017. The design work will continue after the thesis project. MinunLOFT will start to produce the houses in 2018.

10.1 Planning

The creative project started in October 2016 with generating a timetable for the design process. The first intent was to create one house model and the design process was intended to be done in the Summer 2017. The plan changed in the end of November when MinunLOFT wanted to continue the design exploration of three different massing options. The timetable was not renewed after the decision. However, the client was instructed that the design process timetable deadlines moved further due to the change of plans (Figure 36).

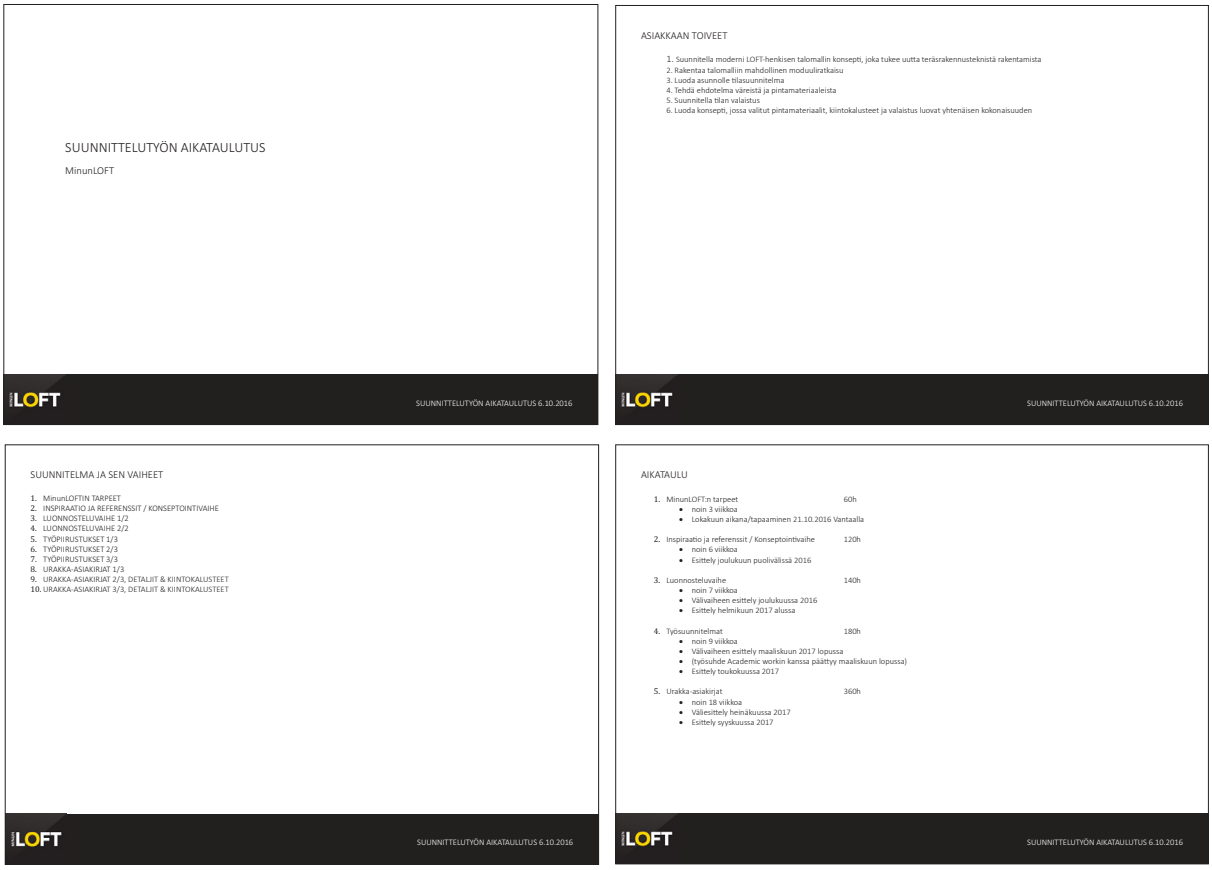


Fig. 36. Timetable

10.2 Research phase

After the creation of the timetable, the creative process continued with a research phase. The research process was based on MinunLOFT's client promise. The promise has stated that MinunLOFT houses are customizable, elegantly designed, ecological, cost and energy efficient with clean indoor air and lofty high ceilings (MinunLOFT 2017).

The research was a foundation for the design concept work. The focus of the research was in the construction process, modular prefabricated houses and housing trends such as ecological living, co-living, working from home and the household sizes. The first part of the research concentrated in the construction process and the required steps in the building planning process. The second part concentrated in the trends, inspiration and modules. The research created an understanding of the limitations and possibilities of the design process. The text portion for the research presentation is in the Appendix 7. The presentation of the research phase is presented in Figure 37.

The research phase included a search for visual references. The visual reference pictures have been left out of the thesis due to user rights. The research presentation has been alterated and changed for the thesis that no non-disclosure materials are revealed.

The requirement clarification for the houses was done during the research presentation with interviewing the founders of MinunLOFT. The clarification was done to set goals for the design project. MinunLOFT wanted to start developing a 100-130 m² rectangle shaped or L-shaped, gabled, wood-facaded house. The intent was to design a house model with three bedrooms, two bathrooms, utility room, a living room, a kitchen and a big dining area with exit doors in the living room and in the lobby. The decision about having a second floor was not made. MinunLOFT requested that the heating system was an underfloor heating and a heat pump. Making a clear project plan was not seen useful, because offering customization for the clients was important.

The aim of the design was to create modern, minimalistic houses, that take influence of Scandinavian traditional wooden buildings. All the models were to follow a lofty ceiling height which creates a spacious and airy atmosphere. The houses were going to be constructed in a factory-controlled environment, transported to the construction site and be combined together.

The research phase discovered that having all the professionals involved in the early phases of the design of a building project, improve the outcome. In the research presentation, the company was instructed to involve an engineer and an architect to take part in the design process.

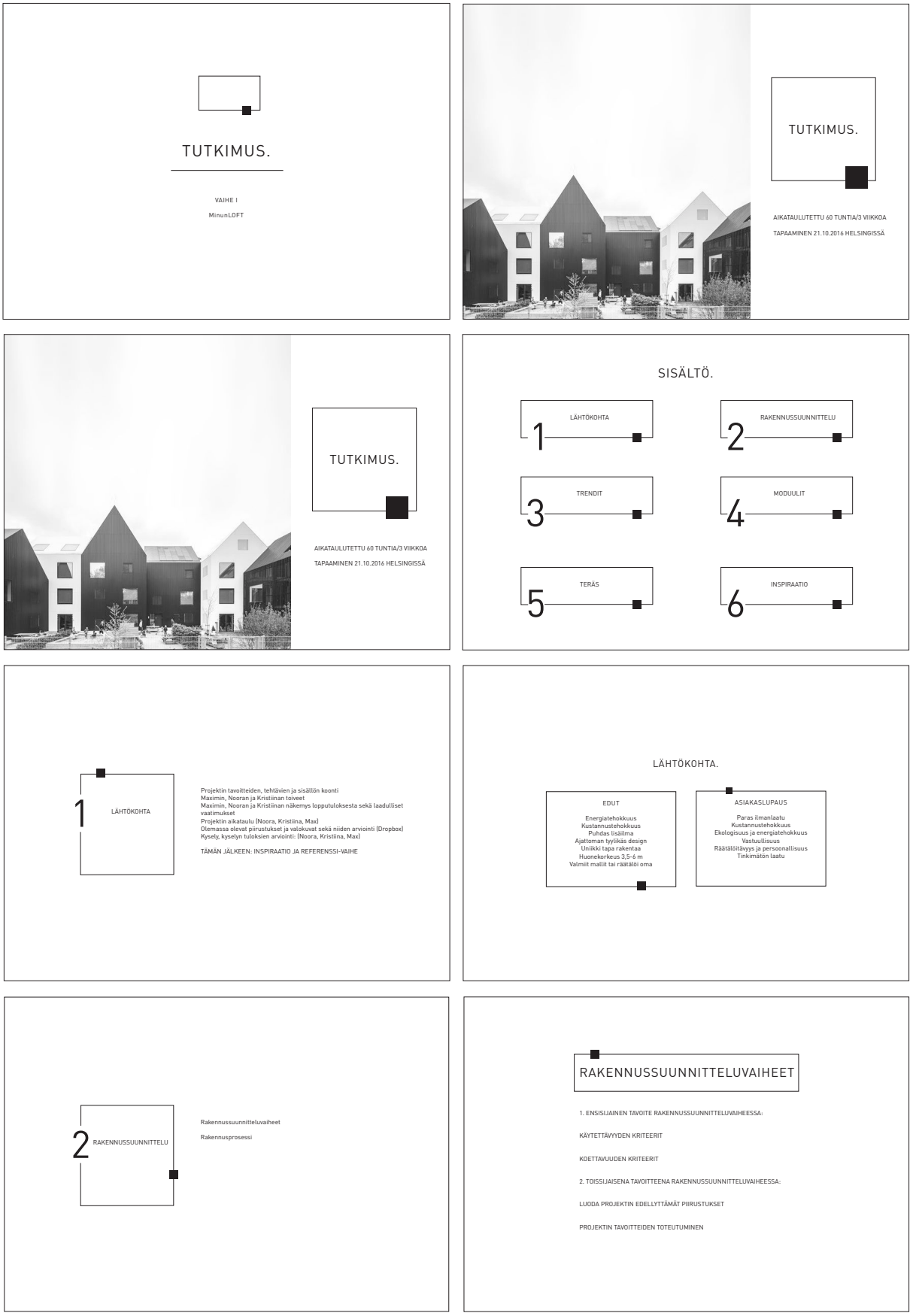


Fig. 37. Research presentation (image

Fig. 37. Research presentation

EKOLOGISUUS

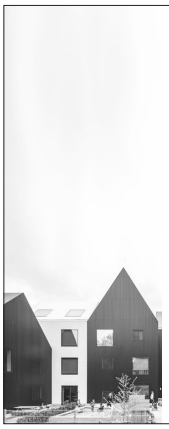
kestävän kehitys
päästöt 2050 mennessä
rakentaminen
40 % energiasta ja luonnonvaroista
40 % kaikista jätteistä ja hiilidioksidipäästöistä
nollaenergiatalo
energiatehokkuusvaatimukset
2020 kaikki uudisrakennukset
suunnitteluyhteistyö
energialaskenta
erityisesti suunnittelun alkuvaiheessa
energiatehokkuustavoite hankesuunnitteluvaiheessa
rakennuttaja sitoutuu
sitouttaa edelleen muut
muuttaminen aiheuttaa ylimääräistä työtä
kirjaus konsulttisopimuksiin
insinöörit, arkkitehdit ja suunnittelijat työskentelevät yhdessä alusta lähtien
ekotalo

TILARATKAISUT TUKEMASSA EKOLOGISTA ASUMISTA

pallo tai kuutio
lämmöneristys ja ilmanpitävyys
hyvä tilankäytön suunnittelu
lämmitettävät neliöt per henki
asukkaiden todellinen tilantarve
päivittäinen liikkuminen
asunnon mukautuminen elämäntilanteisiin ja tyyleihin
asuntoratkaisuiden joustavuus
muuntuvat huonekalut
tilanjakajat

TILARATKAISUT TUKEMASSA EKOLOGISTA ASUMISTA

Muuntojoustava talo
eri elämäntilanteiden tarpeet
laajennettavuus, supistettavuus
erillisen tilan jättäminen vaille lämmitystä



PERSOONALLISUUS JA MUUNTELU

muunteluvaihtelu
omannäköisyys
valkoinen kanvas
yksilöllisyyden toive ja tarve
sosiaalisesti, ekologisesti ja taloudellisesti kestävä
pientaloteollisuus
sarjaräätälöinnin aikaa
modulaarinen rakentaminen

YKSINASUMINEN

1960 asuntokunnan keskikoko oli 3,34 henkeä
2011 enää 2,07 henkeä
Suuret ikäluokat
2010 omakotitalot 144 m2
20 vuodessa 50 %
600 000
ka 1.83 lasta

YHTEISASUMINEN

welive
yksinäisyydenkokemukset
perheen muunnelmat ja sekamuodot
uusperheitä ja samaa sukupuolta olevien puolisoiden perheitä.
yhteisöllistä elämänmuotoa mahdollistavia asuntoratkaisut
maahanmuutto

TYÖSKENTELY KOTONA

etätyö
keskittyvät usein osaamiskeskuksiin
liikkuvuus lisääntyy
virtuaalinen asioiden hoito
työkulttuurin muutos
kommunikoinnin kehittyminen
Wework

DIGITAALISUUS

reaalisen ja virtuaalisen maailman sulautumista
ajan ja paikan sidonnaisuuksien heikkenemisen.
etäläsnäolo

PUUTARHA KAUPUNGISSA

kaupunkiviljely
viherkatto
viherseinä
puutarha kaupungissa

Fig. 37. Research presentation

4

MODUULIT

Moduulirakentaminen

Moduulijärjestelmät

Moduulien kuljetusmitat

MODUULIRAKENTAMINEN

moduuli
modulaarisuus
elementtirakentaminen
pienet materiaalihäviöt
rakennusjätteen kierrätys
70%
uudelleenrakentaminen ja korjaus
resurssit
sääolosuhteet
aikataulu
kustannukset
prosessi kuten elektroniikkateollisuudessa
laatu

MODUULIJÄRJESTELMIÄ

Canon 60-mittajärjestelmä
Oktametri-järjestelmä
Kantamoduuli 1M
Domino
Bungalow Oy: "Kuten haluatte" (1968), Juhani Vainio, 375 cm x 375 cm
Ahlström: Moduli 225 (1968) (Kristian Gullichsen ja Juhani Pallasmaa) 225 cm x 225 cm
Japanilainen
BES-rakennusjärjestelmä ja 3M-mittajärjestelmä

MODUULIEN KULJETUSMITAT

ekologisuuden haitta
päästöjä
kuljetus ja asennusnostot
parempaa lujuutta
erikoisjärjestelyjä ja erikoiskalustoa
kuljetuskustannukset

NEAPO Oy:n enimmäismitat ovat 7 x 22 x 5 metriä
maanteitse kuljetettavien moduulien enimmäismittoja

Kannustalo 4,9 x 14,5 metriä.

Lapponia Leveydet 2400, 3000 ja 3600 mm
Pituudet 5400, 8400 ja 11400 mm
Sisäkorkeus 2400 mm,
huoneistoalat ovat n. 13-41 m2

rakentamisaika tontilla on n. 2-4 viikkoa

5

TERÄS

Teräs moduulirakentamisessa

Teräksen edut ja haitat

TERÄS MODUULIRAKENTAMISESSA

hiilipitoisuus on alle ,7 %
elinkaaren aikana
hyödynnetty asianmukaisesti
80 % A992 teräs
Suomessa lujuusarvo on vähintään S355
S = Rakenneteräs
MinunLOFT S355 terästä
40 % kierrätysterästä
energiatehokkaita rakennusratkaisuja
alhainen lämmönvarastointikyky
valmistus kuluttaa paljon energiaa
materiaalin kestävyys ja kunnossapito
kosteus
ruoste
luonnostaan palamaton materiaali
paloturvallisen materiaali
rakentamiskustannukset kasvavat hiukan
home
puristuslujuus sekä vetolujuus
melkein mihin tahansa muoto, hitsata tai pultata yhteen.
rakentaminen säästää aikaa ja vähentää aikatauluongelmia
matalien rakennusten rakentamisessa meneteltän hyöty
Raaka-aineen hinta sekä rakennuspaikka
energian hinta sekä materiaalin kuljetus

TERÄKSEN EDUT JA HAITAT

EDUT

kevyt ja luja; lujuus-painosuhde hyvä-pienet rakennemitat, keveät rakenteet
liitokset ja kiinnitykset helppoja (hitsattavuus teräkselle ominainen)
myöhemmät suurehkot muutokset helppoja
homogeeninen materiaali
voidaan valmistaa halutuilla ominaisuuksilla
kosteuden vaihteluilla ei ole merkitystä
palamaton aine-hyvä kalutuskestävyys
korroosio etenee yleensä suhteellisen hitaasti

HAITAT

kallis
teräksen lujuuden mahdollistamat hoikat rakenteet voivat johtaa stabiiliusongelmiin (rakenne-suunnittelija ratkaiseel
pehmenee korkeissa lämpötiloissa
haurastuu kylmässä (tosin ei ole ongelma jos valitaan oikean iskusitkeyden omaava teräs)
pinnan korroosio-ongelmat
työstämistä työmaalla pyritään välttämään, joten suunnitelmamuutokset voivat olla vaikeita
rakentamisen jo alettua

6

INSPIRAATIO

Alustava työ

Fig. 37. Research presentation

10.3 Conceptual design phase

The concept design phase for MinunLOFT project started in the beginning of November 2016. The concept idea was developed through the idea of Phi, golden rectangle or the divine proportion. The modularity and the golden proportion was inspiring the proportions of the houses' exteriors. The floor plans were seen as following the modular system and division of the golden rectangle proportions. Jean Arps painting Large Collage was an inspiration for the modularity and represented the switching of the modules in the houses floor plans (Jean Arp 2008, Fig. 38). The concept presentation was given to MinunLOFT in the end of November 2016. Multiple images were used in the concept presentation as inspiration, however the images are not included in the thesis due to image usage rights.

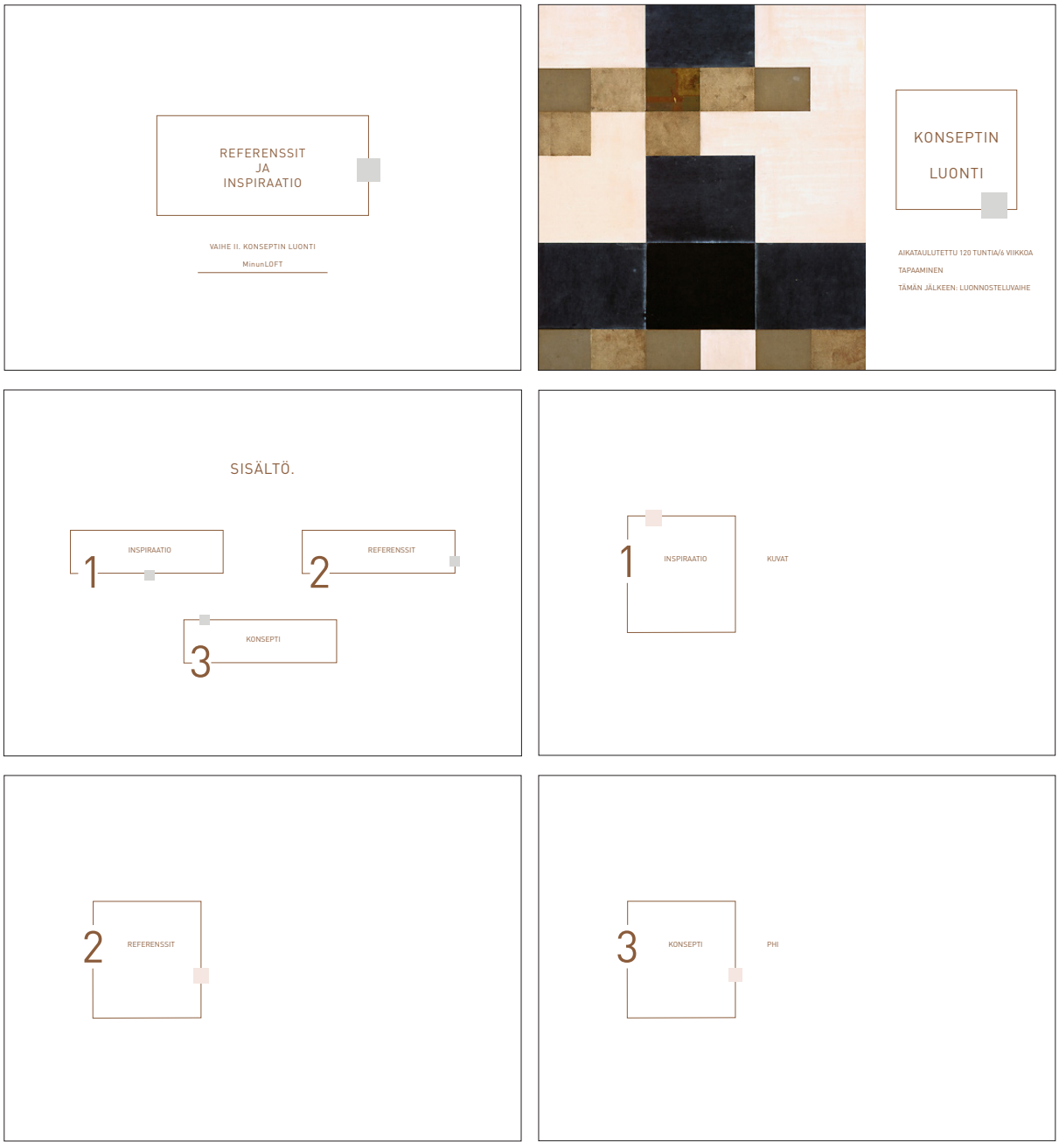


Fig. 38. Concept presentation

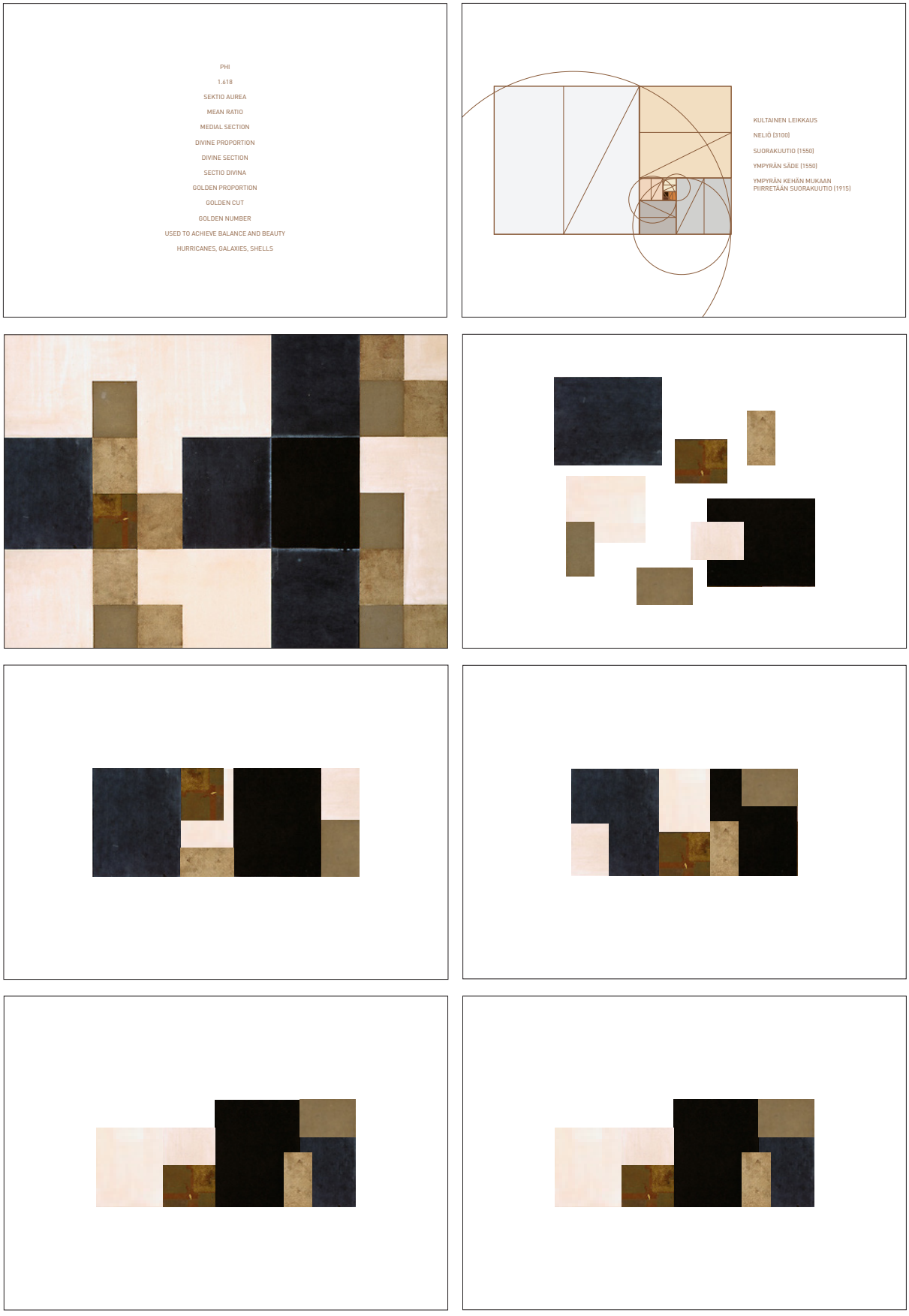


Fig. 38. Concept presentation

10.4 Schematic design phase

The schematic design phase for MinunLOFT started in the end of November 2016 and continued until February 2017. Traditional design means were used for the concept phase; sketching, scale models, 3d modeling, renderings, AutoCAD and design reviews with the client. A limitation of this creative project is that VR was not implemented in the project in the beginning. It would be interesting to assess the design results if the use of VR had been started in this phase.

The first presentation revealed mass model options in which MinunLOFT chose three mass models to design further. The focus was turned from one house onto creating three different house models. Multiple different modular floor plan sketches were made to create the modularity concept (Fig.39).

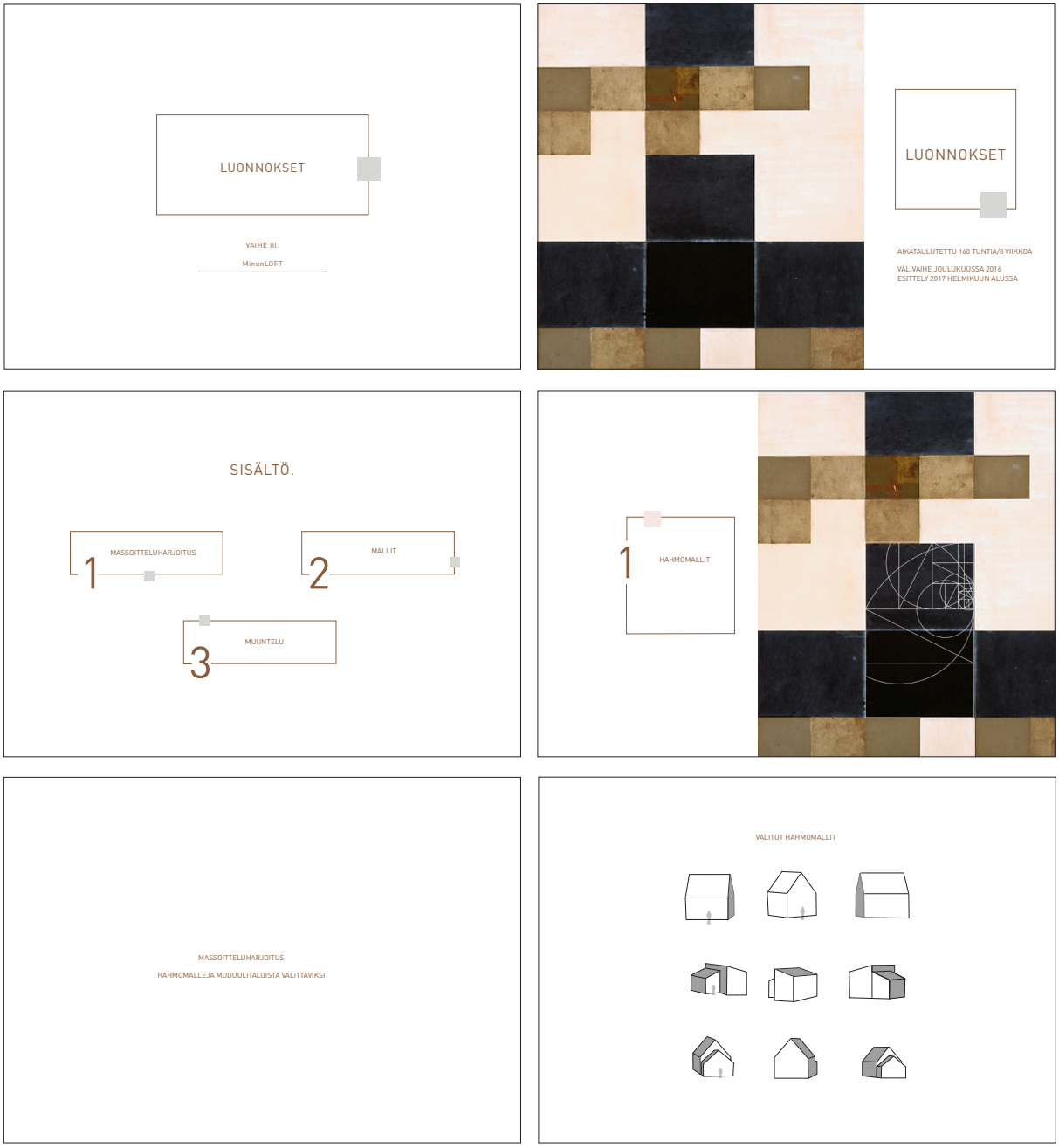


Fig. 39. Schematic design

Fig. 39. Schematic design

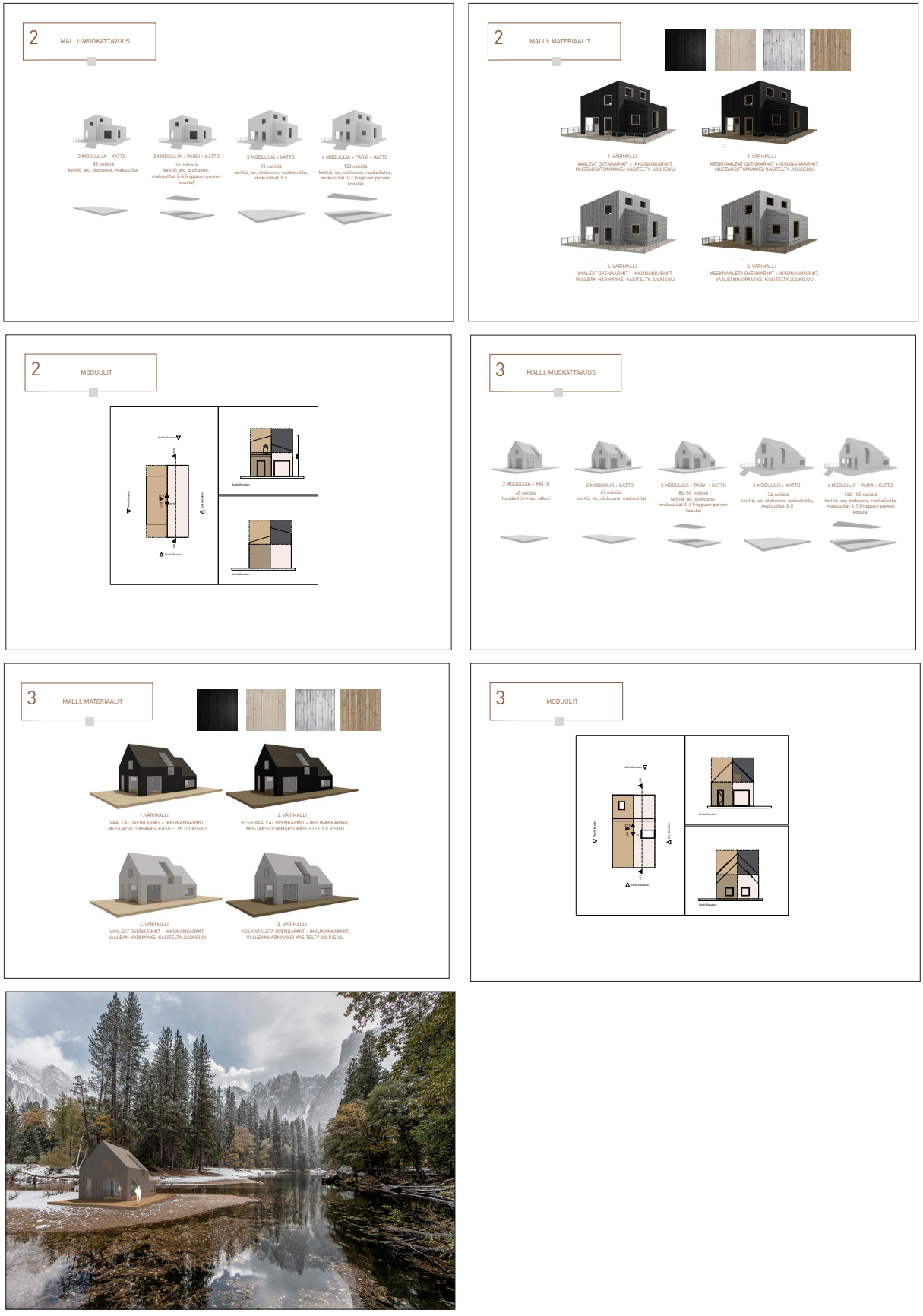


Fig. 39. Schematic design

10.5 Design development

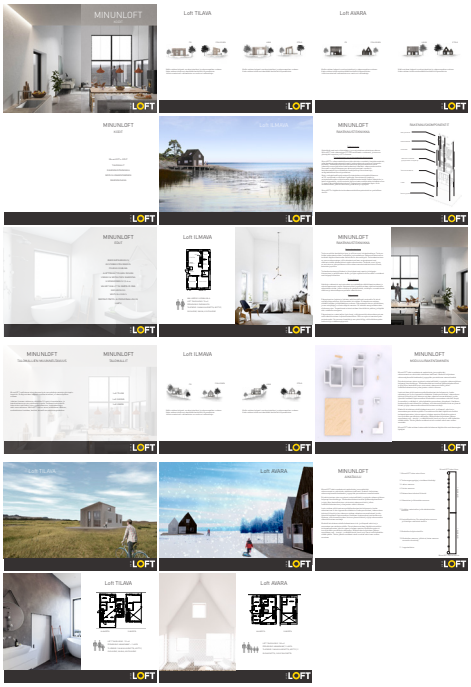
The design development phase started in February 2017 and a midway presentation was presented to the client in March 2017. In the design development, more precise AutoCAD drawings and 3d models were made to define the appearance of the house models. All the houses used the same modular system and were constructed from 3.5 m wide x 4 m high x 11-14 m long modules.

The midway presentation was showing how the design process should continue and recommended the proceeding plan and a list of drawings that need to be developed afterwards (Fig.40).

Fig. 40. Design development presentation

Fig. 40. Design development presentation

2 ESITE



3 MITÄ SEURAAVAKSI?

SUUNNITTELUTYÖN JATKO

TYÖPIIRUSTUSVAIHE
Jatkuu toukokuun loppuun asti (työsopimus loppuu 2.4.2017)

Pohjapiirustukset 1:100 CAD/PDF
Perspektiivikuva
Julkisivut 4 kpl 1:100 CAD/PDF
Alakatot/valaisimet 1:100 CAD/PDF
Leikkauskuvat 1:100 CAD/PDF
Asemapiirros (?)
Tapaamiset

Virtual Reality -työkalu mukaan suunnitteluun

Jatketaan seuraavaan vaiheeseen:
8-10. URAKKA-ASIAKIRJAT 1-3 (360 h) - noin 18 viikkoa
Dokumentti Skaala Formaatti
Julkisivut 1:50 CAD/PDF
Pohjapiirustukset 1:50 CAD/PDF
Alakatot/valaisimet 1:50 CAD/PDF
Leikkauskuvat 1:50 CAD/PDF
Seinäkaaviot 1:50 CAD/PDF
Detaljit vaihtelee CAD/PDF
Seinäkaaviot 1:100 CAD/PDF
Erikoissuunnitelmat
Tuotelista/Materiaalit
Tilakohtaiset ohjeistukset
Tapaamiset

Konsepti
Julkisivu
Tilasuunnitelma
Moduuliratkaisu
Detaljit:
Ovet
Ikkunat
Portaat
Katto
Märkätilat
Valaistus
Pöytätasot
Kaiteet
Kiinteät kalusteet ja niiden mahdollinen verhoilu
Terassi
Värisuunnitelma ja materiaalien valinta

Fig. 40. Design development presentation

Instead of moving to developing the drawings, the design work was focused on marketing materials, because the client materials for the housing fair were a higher priority for MinunLOFT. The company requested for a client brochure, video, posters and a magazine ad as well as updated website images. The material described the construction, models and information about the company. The shift changed the design work towards making the material for the marketing material. The marketing material is presented in the Chapter 11.

Virtual reality was used as a design development tool to improve three floorplans for the marketing materials. 360 tours for clients were provided by using VR. The tours allowed to visit each of the models through the company website. The 360 renderings were made using V-ray and Enscape. SentioVR as a web service provider.

10.5.1 Journal

A weekly design journal of the design development phase was kept for two months when VR was added in the work flow. VR was used as an additional tool with the traditional architectural design tools. Starting the design process with traditional tools, felt natural and comfortable. However, adding VR in the beginning of the design process could have possibly improved the outcome. The Vive headset was not purchased until the design development phase.

The evaluation of the design in VR started with HTC Vive system. The process of getting the VR system to work as a design tool took two weeks, because of technical issues. Setting up VR took several hours and the computer needed to be updated with a new graphics card to get the VR to function. The adoption of VR included a day with a technician that helped with a blue screen error, rebooting the system and installing all the software back to the computer. After the VR software was installed, the VR equipment setting up was simple with the instructions of Vive.

When the first house was in the virtual environment, the trouble was worth the wait. VR environment felt real and immersive. Enscape let the designer to try different user heights with different perspectives. VR helped to understand the space relations better and think alternative options to improve the design. Seeing the space in a natural perspective helped the design process considerably. VR was used in design reviews to make the three house models functional and evaluate the design. 'Stepping in' the houses for the first time helped to adress the design problems and the alteration of the drawings was done with AutoCAD. Several small changes were made especially in the locations of the walls and the position of the staircases. Issues were easier to detect in the natural perspective. Drawings of the houses were corrected and improved with the use of VR.

The interviews with the VR professionals helped to understand which software was good to use for design. Enscape was used as a plug-in of Sketchup. The design development was tested with the use of Unity. However, if Unity had been the only software to work with, the development phase would have taken more time, because the software requires C# programming language knowledge.

The VR hardware worked almost flawlessly most of the time. However, sometimes the equipment needed to be rebooted. The reboot took a few minutes but it was frustrating. Motion sickness happened twice during the two months period. The display started to be heavy and strain the eyes after using it for several minutes. The wires made it difficult to move around the space.

The journal offered some insight into challenges and benefits of the design process. However, no major findings were made during the writing process. More useful information was collected after the process was finished. There is, therefore, a definite need for time in the processing of the information in VR. The user is intensively a part of the immersive experience and letting the processing time, could give more fruitful information. A shorter version of the design journal is included in the Appendix (Appendix 8).

10.5.2 The future of the design process

The design work continues with the construction documentation and the construction administration phase. In the construction documentation phase, detailed documents such as working drawings and written specifications are developed. After the documents are ready, they are released for bidding (Cambell 2003).

The construction documentation phase started in November 2017. The detailed drawings are developed together with the engineering company Ramboll. In this phase the floor plans, sections, elevations and other written specifications are finalized. The collaborating with other professionals will be continued with using VR and Revit.

10.5.3 Evaluation of the design process

The client has been happy with the progress and the result of the design work. Several potential clients have contacted the company and wanted more details from the houses.

The design process has been demanding. The product features, design goals, the limited resources of the company and the changing plans have been challenging. The design results could have benefited from the knowledge of the building engineer earlier in the process, however, the future collaboration with the engineering company is promising.

The ecological perspective of the design has to be discussed with the engineering company. MinunLOFT's aspiration of the ceiling height and big windows increase the reguired heating in the cold northern countries and therefore the electricity use could be an issue. Recommended solar roofs and the geothermal heating and a powerful insulation improve the ecological aspect of the houses.

11

DESIGN OUTCOMES

Image 11.

11

DESIGN OUTCOMES

This chapter presents the design outcomes of design development phase for marketing purposes.

11.1 Housing fair material

The housing fair material was produced during the design development phase. The needed material was a magazine ad, two posters, a give-away leaflet and a video showing the construction process of MinunVALO, which is the house built for the housing fair.

The magazine ad was developed for the interior magazine Deko. Ad was half-a-page magazine ad. The pictures used were taken in MinunVALO on the previous week by Deko magazine. The posters were shown in MinunVALO and they were showing all three new house models. The give-away leaflet was given to the visitors who came to MinunVALO during the fairs and wanted to know more about MinunLOFT.

11.2 MinunLOFT client brochure

The client brochure is presenting MinunLOFT construction process, models and company information for prospect customers. The brochure has been used in business meetings with collaboration partners as well as investment meetings. It is made to give a brief introduction of the company and the product. The client brochure size is folded A3 and each page is portrait A4.

11.3 House model brochures

The three houses are called Loft Tilava, Loft Ilmava and Loft Avara. The house model brochures each share more details about a specific model. These are made for a client that wants more details and see pictures of each house model. The size of the brochure is a 2 landscape A4. The material for the thesis has been altered to fit a vertical page.

11.4 360 tours

360 renderings were made for the company's Internet pages to allow the touring of the virtual space with the use of VR headset, computer screen or an ipad. The tours were made with SentioVR. SentioVR enables 360 tours of a space through their web service. Each house has a 360 VR tour that the clients can access through the MinunLOFT website. SentioVR is uploaded with panoramic renderings of the space and the pictures are downloaded in the service with additional information.

CLIENT BROCHURE

MINUNLOFT

KODIT

MINUNLOFT

KODIT

MINUNLOFTIN EDUT

TALOMALLIT

RAKENNE JA RD-PAALUPOHJA

RAKENNUSTEKNIIKKA

MODUULIRAKENTAMINEN

RAKENNUSAIKA

JULKISIVUMATERIAALIT

TERVE TALO

MINUN LOFT

MINUNLOFT

EDUT

ENERGIATEHOKKUUS

KUSTANNUSTEHOKKUUS

PUHDAS SISÄILMA

AJATTOMAN TYYLIKÄS DESIGN

UNIIKKI & NOPEA TAPA RAKENTAA

AVARA HUONEKORKEUS (JOPA YLI 6 METRIÄ)

VALMIIT MALLIT, JOITA ON HELPPO RÄÄTÄLÖIDÄ

EKOLOGISUUS

VASTUULLISUUS

PERSOONALLISUUS

LAATU

MINUN LOFT

MINUNLOFT

TALOMALLIEN MUUNNELTAVUUS

MinunLOFT-mallistossa on pohjaratkaisuja moneen tarpeeseen ja käyttöön. Pohjaratkaisut soveltuvat sekä asuin- ja vapaa-ajan asunnoiksi. Malleja voidaan helposti muuttaa toiveittesi ja rakennuspaikan mukaan.

LOFT kodissa on tilantuntua. Huonekorkeus voi parhaimmillaan ylittää jopa 6m. Teräksestä valmistetun talon etuina ovat materiaalin lujuuden, palamattomuuden ja kulutuskestävyyden lisäksi helppo muunneltavuus.

MinunLOFT-koti on avara, kestävä, terveellinen, energiatehokas sekä ennen kaikkea asukkaansa näköinen.

MINUNLOFT

TALOMALLIT

LOFT TILAVA

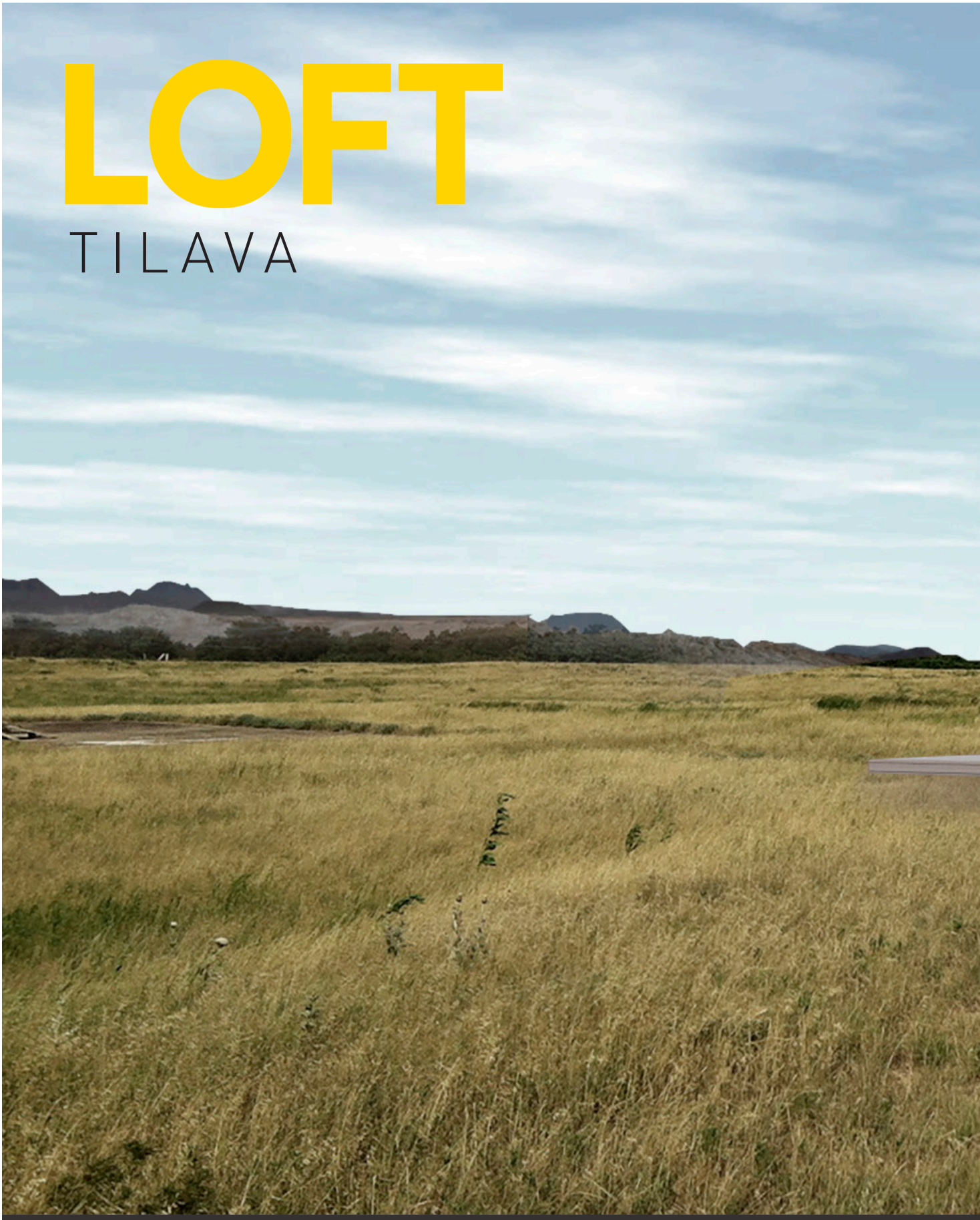
LOFT ILMAVA

LOFT AVARA

MINUN LOFT

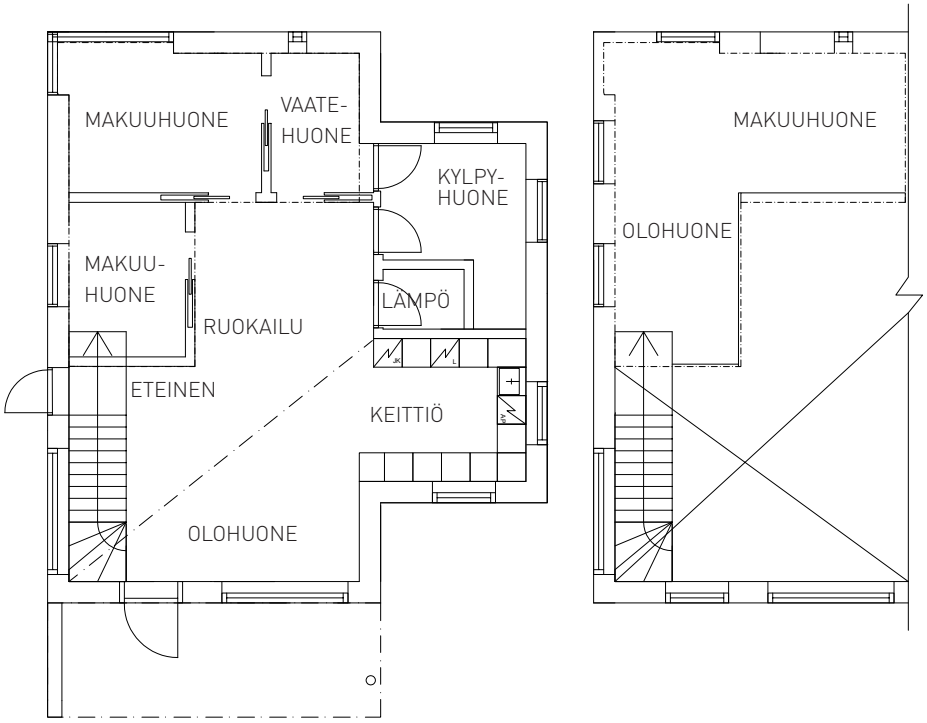
LOFT

TILAVA



MINUN LOFT

LOFT TILAVA



ALAKERTA YLÄKERTA

LOFT TALON KOKO: 110 m2

PERHEKOKO: 4 HENKEÄ

TILATARVE: 3 MAKUUHUONETTA, KEITTIÖ,

OLOHUONE, SAUNA, KYLPYHUONE

MINUN LOFT

LOFT

TILAVA

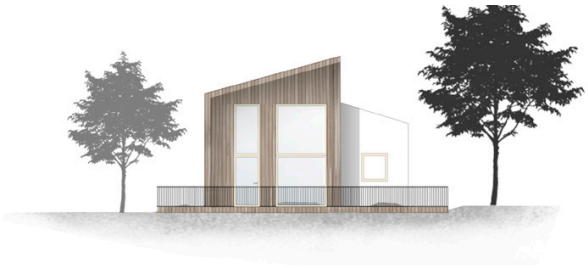
ITÄ

POHJOINEN

Mallia voidaan helposti muuttaa toiveittesi ja rakennuspaikan mukaan.
Katto voidaan tehdä aurinkosähköä keräävistä tiilipaneeleista.

LÄNSI

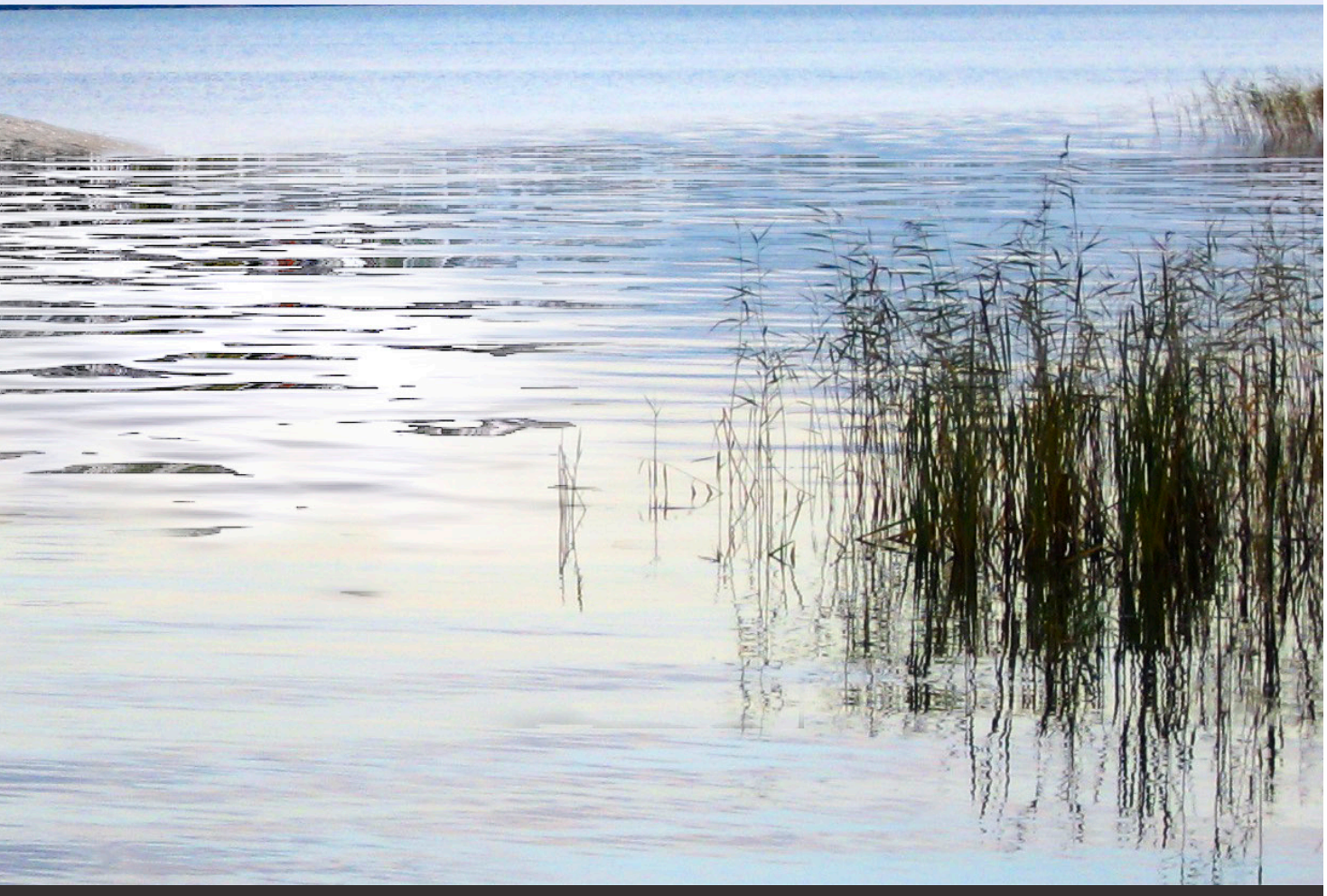
ETELÄ



MINUN LOFT

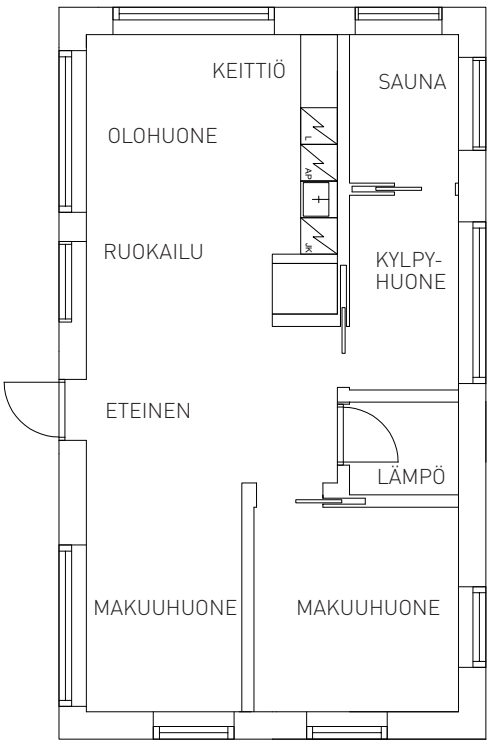
LOFT

ILMAVA



MINUN LOFT

LOFT ILMAVA



MALLIVERSIO: KESÄHUVILA

LOFT TALON KOKO: 70 m2

PERHEKOKO: PARISKUNTA + VIERASPETI

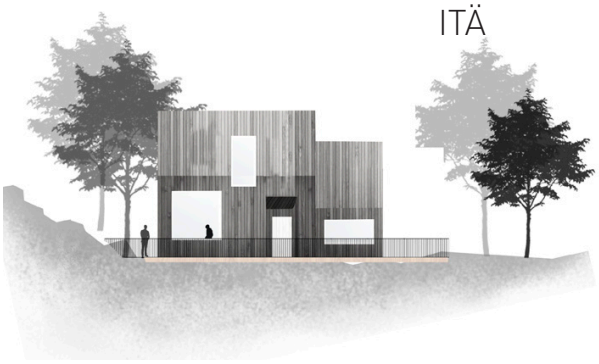
TILATARVE: 2 MAKUUHUONETTA, KEITTIÖ,
OLOHUONE, SAUNA, KYLPYHUONE

MINUN LOFT

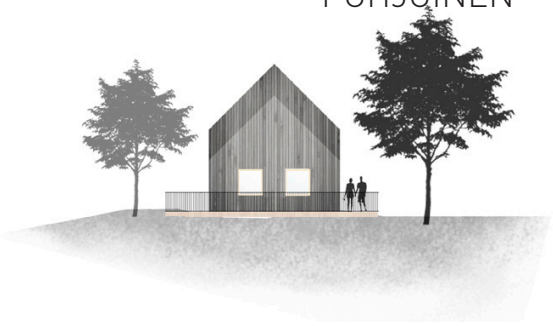
LOFT

ILMAVA

ITÄ



POHJOINEN



Mallia voidaan helposti muuttaa toiveittesi ja rakennuspaikan mukaan.
Katto voidaan tehdä aurinkosähköä keräävistä tiilipaneeleista.

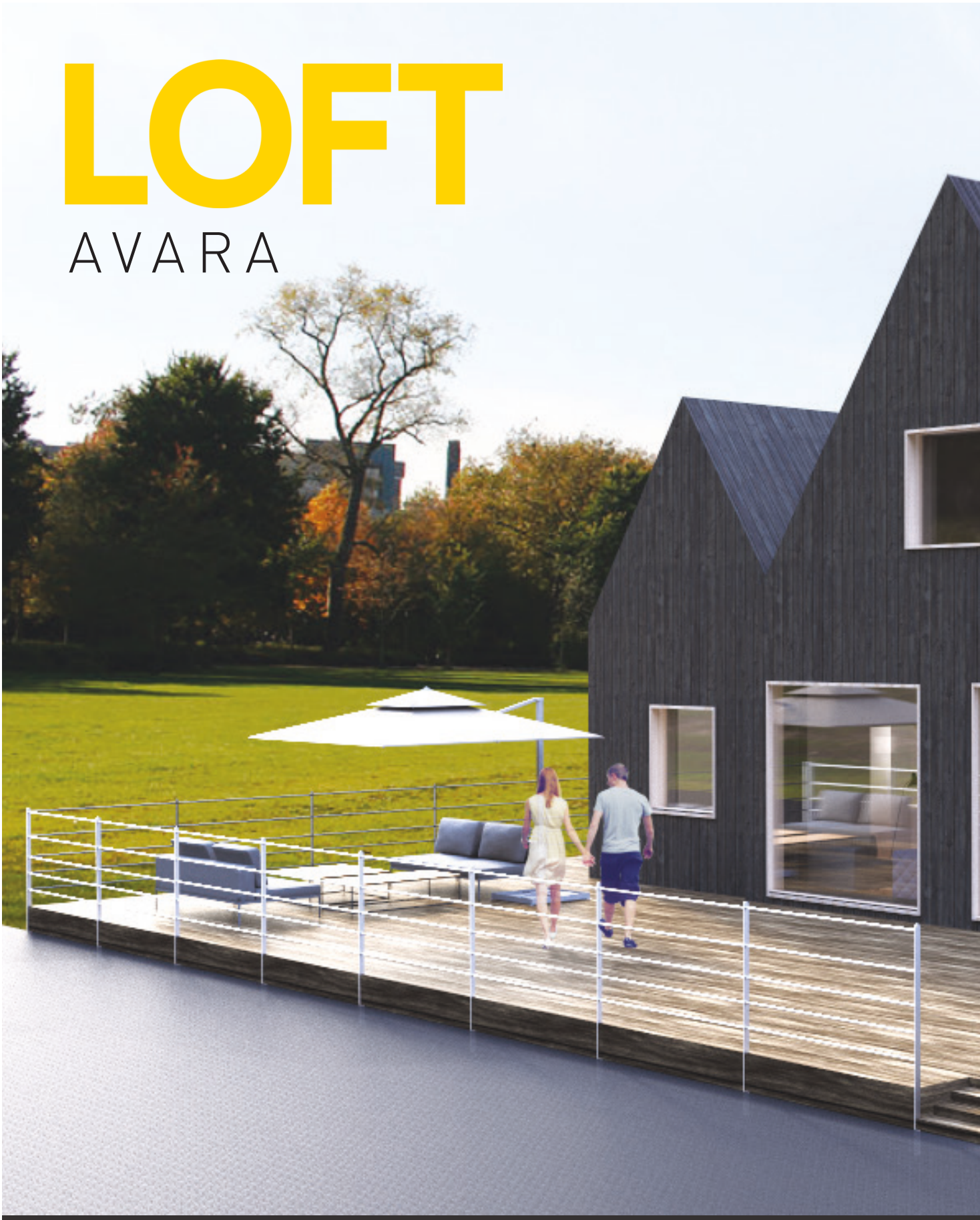
LÄNSI

ETELÄ

MINUN LOFT

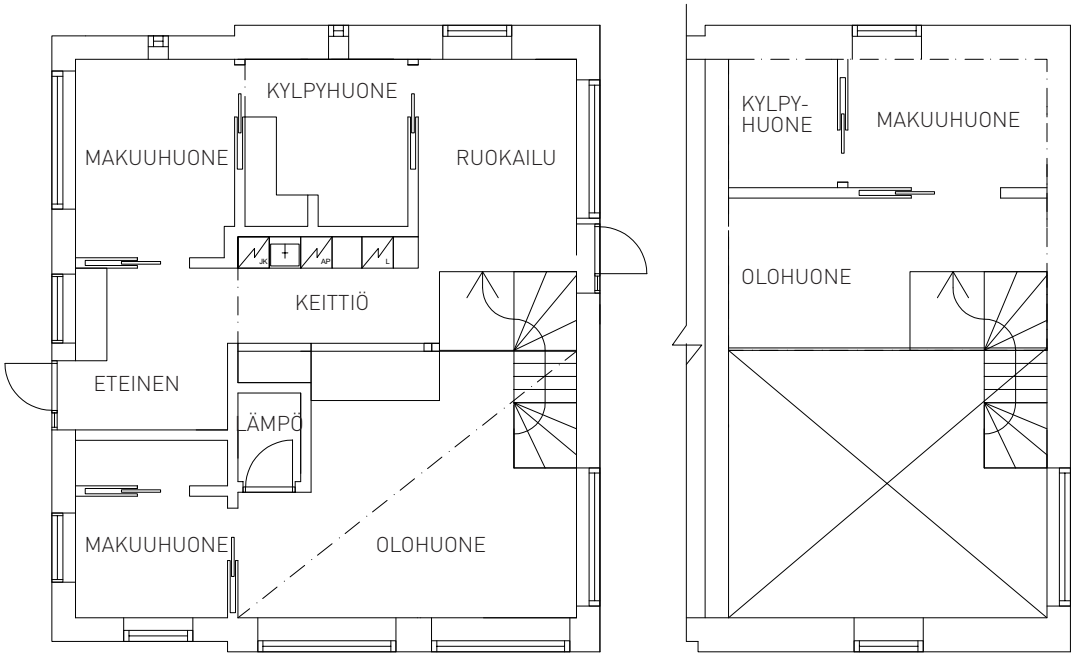
LOFT

AVARA



MINUN LOFT

LOFT AVARA



ALAKERTA YLÄKERTA

LOFT TALON KOKO: 150 m2

PERHEKOKO: VANHEMMAT, 2 LASTA

TILATARVE: 3 MAKUUHUONETTA, KEITTIÖ, 2 OLOHUONETTA, 2 KYLPYHUONETTA

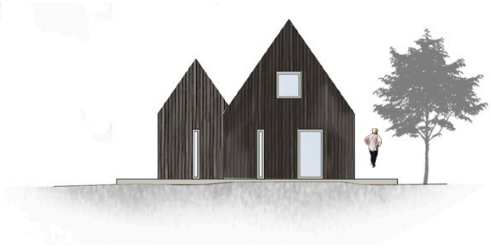
MINUN LOFT

LOFT

AVARA

ITÄ

POHJOINEN



Mallia voidaan helposti muuttaa toiveittesi ja rakennuspaikan mukaan.
Katto voidaan tehdä aurinkosähköä keräävistä tiilipaneeleista.

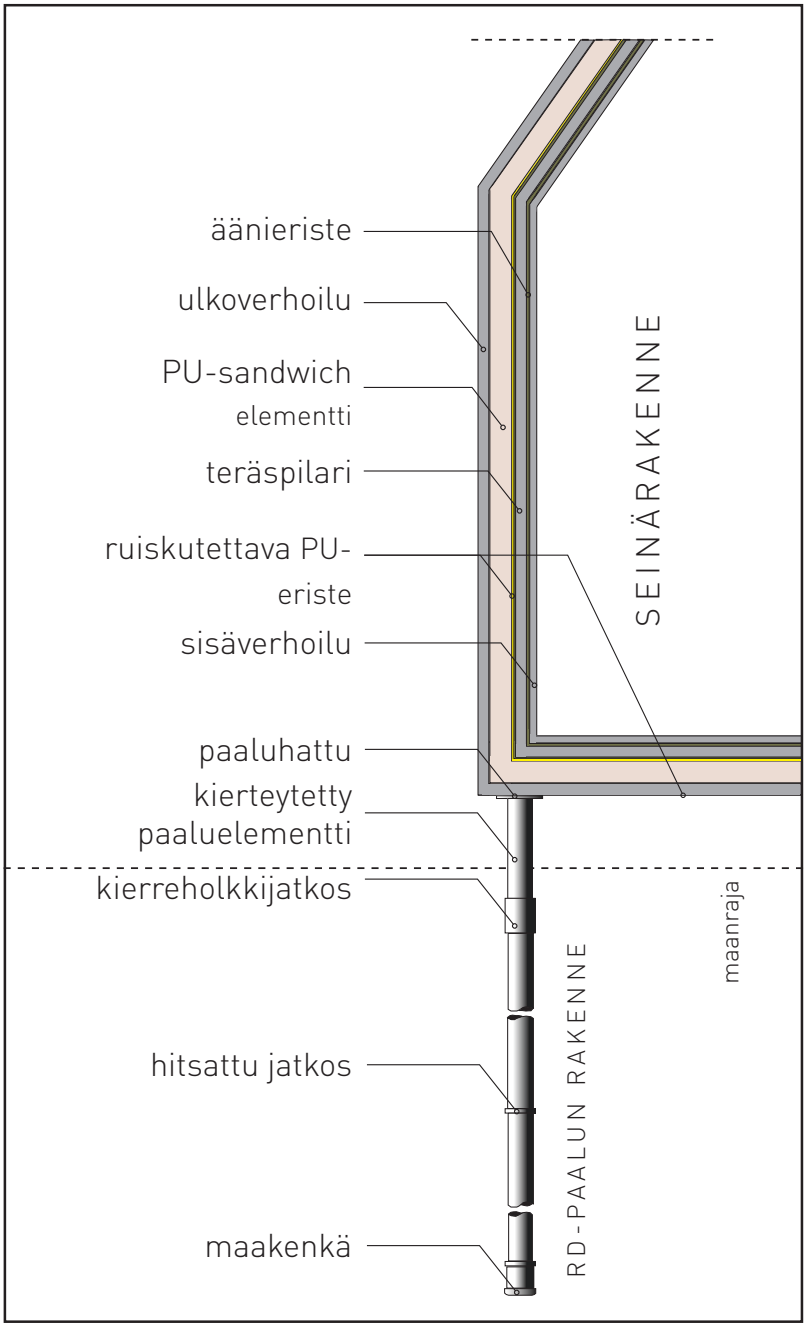
LÄNSI

ETELÄ

MINUN LOFT

MINUNLOFT

RAKENNE JA RD-PAALUPOHJA



MINUNLOFT

SEINÄRAKENNE

MinunLOFTin moduulien seinärakenteet koostuvat sandwich-kevytelementeistä. Kevytelementit koostuvat polyuretaaniytimestä, jonka molemmin puolin on integroitu pintalevy. Seinärakenne ei sisällä sellaisia orgaanisia aineita, jotka mahdollistaisivat kasvualustan home- ja kosteusvaurioille. MinunLOFTin seinärakenne ja talomallien hyvä ilmanvaihtojärjestelmä luovat raikkaan ja puhtaan sisäilman.

Polyuretaani-sandwich-kevytelementeillä on mahdollista luoda parempi, lämmöneristys, energiatehokkaat lämmitysratkaisut ja alhaisempi sähkön- ja veden kulutus. Takaamme markkinoiden tehokkaimman U-arvon, eli lämmönläpäisykertoimen ruiskutettavalla polyuretaanilla.

Teräs on erittäin kestävä ja luja rakennusmateriaali. MinunLOFT käyttää rakenteissa palosuojattua ja pintakäsiteltyä S 355 terästä. MinunLOFT-talot rakennetaan CE 1090 sertifikaatin mukaisesti. Teräsrunko mallinnetaan 3D-suunnitteluohjelmalla. Tehokas valvonta ja ensiluokkainen laatu ovat ehdoton osa rakentamista. Asennuksessa ja valmistuksessa OHAS 18001 työturvallisuussertifikaatti takaa turvallisen projektitoteutuksen alusta loppuun.

MINUN LOFT

MINUNLOFT

RAKENNUSTEKNIIKKA

Rakentaminen

Käytettävät osat ovat mittatarkkoja, ja ne valmistetaan valvotuissa oloissa. MinunLOFT-talo rakennetaan CE 1090 sertifikaatin mukaisesti, ja teemme yhteistyötä Inspectan ja VTT:n kanssa.

Tehdasvalmistuksen ja teräsrunkorakenteen ansiosta kotisi valmistuu nopeasti Talomallit koostuvat moduuleista, jotka rakennetaan valvotuissa tehdasolosuhteissa Mikkelissä, Etelä-Savossa. Tehdasvalmistus mahdollistaa tarkan laadunvalvonnan sekä vähentää materiaalikulutusta, sillä rakennusmateriaalit voidaan kierrättää ja käyttää hyödyksi tehokkaammin. Talomallien runkorakenteen pystytys voidaan toteuttaa nopeasti, sillä teräsrakenteen mittatarkat osat kootaan yhteen pultti- ja hitsausliitoksilla. Keskikokoisen talon perusrakenne voidaan pystyttää jopa alle viikossa.

Tehdasvalmistus ei ole riippuvainen sääolosuhteista, jolloin rakennushankkeen aikataulun ja budjetin hallinta on helpompaa. Valmiit moduulit kuljetetaan valmiina elementteinä rakennuskohteeseen ja Seinärakenne MinunLOFTin moduulien seinärakenteet koostuvat sandwich-kevytelementeistä. Kevytelementit koostuvat polyuretaaniytimestä, jonka molemmin puolin on integroitu pintalevy. MinunLOFTin seinärakenne ja talomallien hyvä ilmanvaihtojärjestelmä luovat raikkaan ja puhtaan sisäilman.

Polyuretaani-sandwich-kevytelementeillä on mahdollista luoda parempi lämmöneristys, energiatehokkaat lämmitysratkaisut sekä alhaisempi sähkön- ja veden kulutus

RAKENNUSKOMPONENTIT

Ovet ja ikkunat

Kattorakenteet

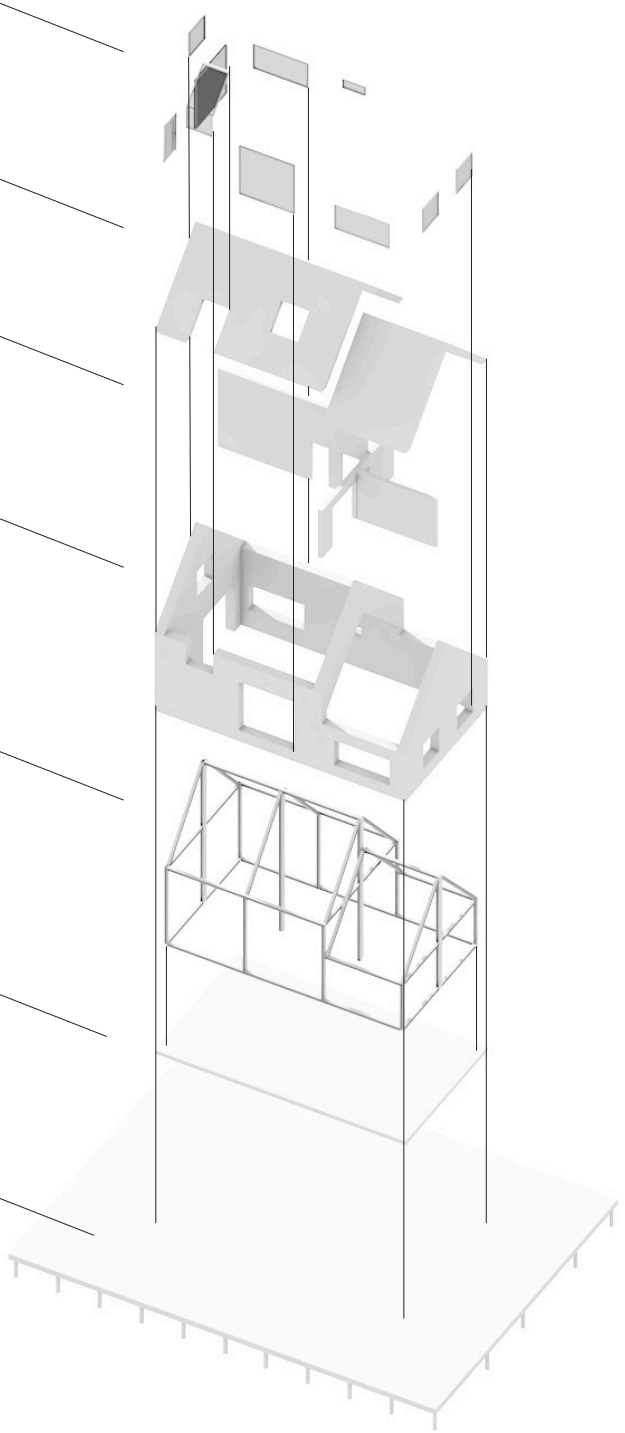
Sisäseinät

Ulkoseinä-rakenteet
ja polyuretaani-eristyslevyt

Teräsrunkorakenne

Lattia

Terassi ja pilarit



MINUN LOFT

MINUNLOFT

RAKENNUSTEKNIIKKA

Teräsrakentaminen

Teräs on erittäin kestävää ja lujaa, ja sillä on suuri kulutuskestävyys. Teräs on palamatonta oikein suojattuna ja pinnoitettuna. Rakennusmateriaalina teräksen käytössä kosteuden vaihtelulla ei ole merkitystä. Teräsrakentaminen on varma rakennustapa, sillä rakentamisvaiheen suojaustarpeet ovat vähäiset eivätkä sääolosuhteet rajoita rakentamista. Teräksen suuri lujuus on ominaisuus, joka poikkeaa muista rakennusmateriaaleista kuten tiilestä, betonista ja puusta.Teräsrakentamisessa liitokset ja kiinnitykset ovat nopeita ja helppoja tehdä hitsaamisen ja pulttiliitosten avulla, ja suuretkin muutokset ovat helppoja toteuttaa myös jälkikäteen.

Polyuretaani

Rakenteiden höyrysulkuna toimii ruiskutettava polyuretaani, joka ei voi homehtua tai mädäntyä. Eristepaksuus voidaan säädellä tarpeen ja käyttökohteen mukaan. Polyuretaanieriste on pitkäikäinen ja sen eristyskyky ja muoto säilyvät samoina niin kylmissä kuin kuumissakin sääolosuhteissa. Polyuretaanieriste säästää energiaa koko talon elinkaaren ajan. Tarpeettomat eristeet voidaan kierrättää tai polttaa.

Polyuretaani on materiaalina hyvin kevyt, mikä pienentää rakennuksen painoa sekä säästää eristeen kuljetuskustannuksia. Polyuretaanin palo-ominaisuutena on uudelleen syttymistä hidastava pinnan hiiltyminen ja itsestään sammuvuus sekä palon leviämistä.

MINUN LOFT

MINUNLOFT

MODUULIRAKENTAMINEN

MinunLOFT talot muodostuvat moduuleista, jossa vakioidut rakennusosat on valmistettu etukäteen teollisesti. Moduulit kuljetetaan rakennustyömaalle koottavaksi ja pysyvään perustukseen asennettavaksi (teräspaaluperustus).

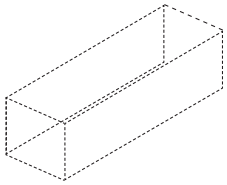
Esivalmistamisen etuna on pienet materiaalihäviöt ja syntyvän rakennusjätteen helpompi kierrätettävyys. Tehdasolosuhteissa tasaiset työskentelyolosuhteet ja työn jäljen kontrolloiminen minimoivat rakennusvirheitä, jolloin uudelleenrakentamisen ja korjaustarpeen määrä vähenee.Laatu voidaan pitää tasaisena paikallarakentamista helpommin, koska rakentaminen ei ole riippuvaista sääoloista. Koska perustukset, rakennuksen tekniset liitännät ja itse rakennus voidaan rakentaa samanaikaisesti ja näin lyhentää hankkeen läpimenoaikaa. Moduuleihin asennetaan valmiiksi lämpö, ilmanvaihto ja sähköpiirit, jotka kytketään asennuksen yhteydessä.

Hankkeen kustannukset ovat tarkemmin tiedossa, sillä elementtiurakan hinta on yleensä kiinteä ja lyhyt rakennusaika vähentää kustannusriskejä. Moduulit toimitetaan rekalla kokonaisena sisä- ja ulkopuoli valmiina ja asennetaan perustuksien päälle. Perustuksena käytetään laadukasta teräspaaluperustaa, joka on nopea ja helppo asentaa. Moduulitalon kuljetuksen jälkeen asennetaan vesi-, viemäri- ja sähköliitännät, kamiina ja hormi sekä kytketään sähköt päälle. Tämän jälkeen asukkaat voivat muuttaa valmiiseen omaan asuntoon. MinunLOFT talot voidaan tulevaisuudessa kustomoida haluttaessa käyttämään myös aurinkoenergiaa hyödyksi.

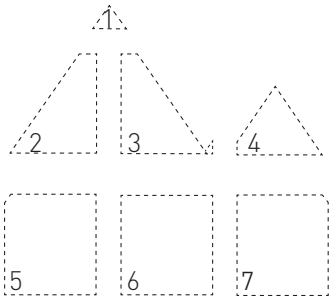
MINUNLOFT

MODUULIRAKENTAMINEN

1. Talot koostuvat tehdasvalmistetuista moduuleista maksimimitat: korkeus 3.5m, leveys 3.5m, pituus 3.5-12m



2. Moduulit kuljetetaan valmiina rakenteina rakennuskohteeseen



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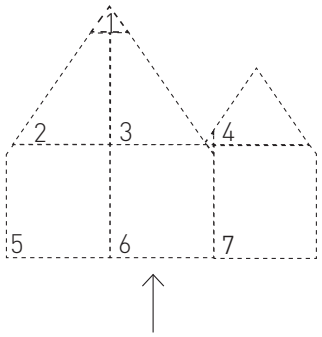
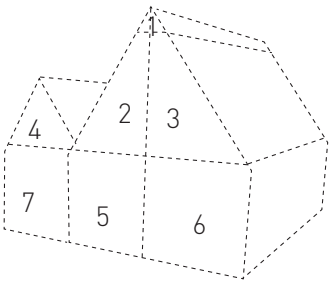


4. Moduulit liitetään toisiinsa, jonka jälkeen asukas voi muuttaa sisään. Moduulit on suunniteltu niin, että rakennukseen pystytään lisäämään vaivattomasti extramoduuli jälkeenpäin.



MINUN LOFT

MINUNLOFT

AIKATAULU

MinunLOFT talot muodostuvat moduuleista, jossa vakioidut rakennusosat on valmistettu etukäteen teollisesti. Moduulit kuljetetaan rakennustyömaalle koottavaksi ja pysyvään perustukseen asennettavaksi.

Esivalmistamisen etuna on pienet materiaalihäviöt ja syntyvän rakennusjätteen helpompi kierrätettävyys. Tehdasolosuhteissa tasaiset työskentelyolosuhteet ja työn jäljen kontrolloiminen minimoivat rakennusvirheitä, jolloin uudelleenrakentamisen ja korjausten määrä vähenee.

Laatu voidaan pitää tasaisena paikallarakentamista helpommin, koska rakentaminen ei ole riippuvaista sääoloista. Koska perustukset, rakennuksen tekniset liitännät ja itse rakennus voidaan rakentaa samanaikaisesti ja näin lyhentää hankkeen läpimenoaikaa. Hankkeen kustannukset ovat tarkemmin tiedossa, sillä elementtiurakan hinta on yleensä kiinteä ja lyhyt rakennusaika vähentää kustannusriskejä.

Moduulit toimitetaan rekalla kokonaisena sisä- ja ulkopuoli valmiina ja asennetaan perustuksien päälle. Perustuksena voidaan käyttää esimerkiksi teräspaaluperustaa, joka on nopea ja helppo asentaa. Moduulien paino ei tuo rajoituksia perustuksia valittaessa. Moduulitalon kuljetuksen jälkeen asennetaan vesi-, viemäri- ja sähköliitännät, kamiina ja hormi sekä kytketään sähköt päälle. Tämän jälkeen asukkaat voivat muuttaa valmiiseen omaan asuntoon.

MinunLOFT talon suunnittelu

Suunnittelu, perustukset ja maalämpö

Teräsrungon pystytys ja teräksen käsittelyt

Lattian asennus

Seinien asennus

Rakennuksen tekniset liitännät

Ulkoseinien ja ikkunoiden asennus

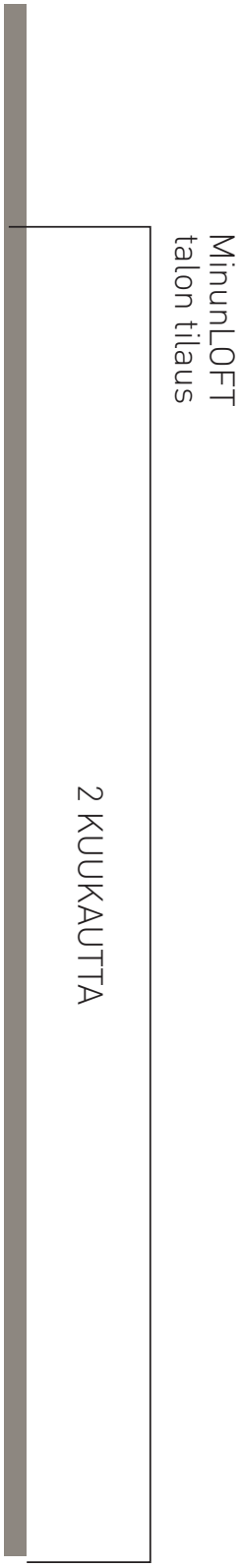
Sisätilan materiaalien ja kiintokalusteiden asennus

Kontrollitarkistus, Perustuspilarien asennus ja liitäntöjen valmistelu tontilla

Moduulien kuljetus tontille

Moduulien asennus, julkisivut, katon asennus remontin viimeistely

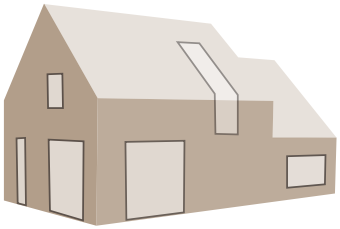
Lopputarkistus



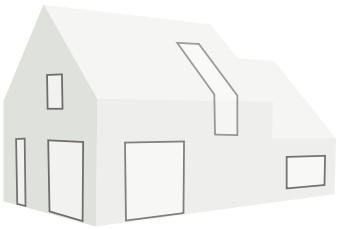
MINUN LOFT

MINUNLOFT

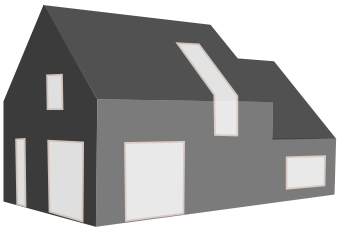
ULKOVERHOILUVAIHTOEHDOT

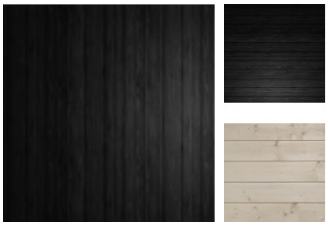


SIPERIANLEHTIKUUSI
+ mustat tai vaaleat
ikkuna- ja ovenkarmit



RAPATTU
Rappaaminen tehdään
talon pystytyksen
jälkeen paikan päällä
+ mustat tai vaaleat
ikkuna- ja ovenkarmit





MAALATTU
PUUVERHOILU
+ mustat tai vaaleat
ikkuna- ja ovenkarmit

MINUNLOFT

TERVE TALO

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Terve Talo -sertifikaatti täydentää MinunLOFTin teräsrakennustekniikkaa. Seinärakenteemme ei sisällä orgaanisia aineita, mikä ehkäisee mahdollisten kosteus- ja homevaurioiden syntymistä. MinunLOFTin seinärakenne ja talomallien hyvä ilmanvaihtojärjestelmä luovat raikkaan ja puhtaan sisäilman.

Terve Talossa tulee olla tarkkaan määritelty rakennussuunnittelu, talotekninen suunnittelu, sisustussuunnittelu, rakentamisen valmisteluvaiheet, rakentamiseen liittyvät työmaavaiheet, kosteuden hallinta ja toteutus työmaalla, puhtauden hallinta ja toteutus työmaalla sekä käyttöönottomittaukset.

VTT valvoo kriteerien täyttymistä ja vaatimusten noudattamista tarkkaan. Rakentamisen aikana on oltava esimerkiksi jatkuva videovalvonta. Lisäksi VTT tekee paikan päällä erilaisia tarkastuskäyntejä, mittauksia ja pistokokeita.

Kaikkien rakennusmateriaalien ulkopinnoista oviin ja ikkunoihin sekä sisäpintoihin, maaleihin, lattiamateriaaleihin ja kaapistoihin saakka on oltava tutkitusti turvallisia ja vähäpäästöisiä. Mikäli rakentamisessa käytetään muita kuin M1-luokiteltuja rakennusmateriaaleja, niin emissiovaatimusten täyttyminen pitää osoittaa muulla tavalla (esim. EU-LCI). Muut kuin sisäilmaan tai ilmanvuotoreitteihin rajoittuvat materiaalit voidaan arvioida erikseen.

Vaatimukset perustuvat tutkittuun kokemukseen siitä, mitkä ovat riskitekijöitä rakentamisessa ja mitä pitäisi välttää.

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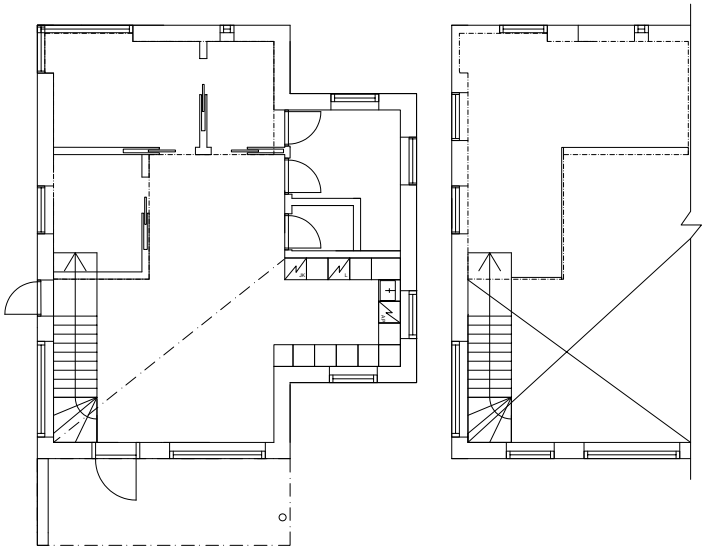
TILAVA

Tilava on moderni omakotitalo. Moduulien lukumäärästä riippuen, Loft Tilava voidaan tehdä 45-80 neliön kokoisena talopakettina. Olohuoneen kattokorkeus on 3.5-5m.

ESIMERKKIPOHJA



ALAKERTA YLÄKERTA

POHJAPIIRUSTUS

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Esimerkkipohja on tehty nelihenkiselle perheelle. Talossa on 110 neliötä ja se koostuu kuudesta moduulista. Talossa on kolme makuuhuonetta, keittiö, kaksi olohuonetta ja kylpyhuone. Talon tekniikkamoduuliin kuuluu kaikki vesikytkentää tarvitsevat huoneet; keittiö, kylpyhuone sekä tekninen tila. Yläkerrassa on tilaa toiselle olohuoneelle, työtilalle ja makuuhuoneelle.

MinunLOFT:n verkkosivuilla voit tutustua tarkemmin esimerkkipohjaan 360 asteen kierroksen avulla.

Varustelutaso: Pintamateriaalit, keittiö, kodinkoneet, portaat,(sauna), LVI-työt, sähkötyöt, lämmitysyksikkö (maalämpö tai muu), data-kytkennät.

SEINÄRAKENNE

MinunLOFTin moduulien seinärakenteet koostuvat sandwich-kevytelementeistä. Kevytelementit koostuvat polyuretaaniytimestä, jonka molemmin puolin on integroitu pintalevy. Seinärakenne ei sisällä orgaanisia aineita, mikä ehkäisee mahdollisten kosteus- ja homevaurioiden syntymistä. MinunLOFTin seinärakenne ja talomallien hyvä ilmanvaihtojärjestelmä luovat raikkaan ja puhtaan sisäilman.

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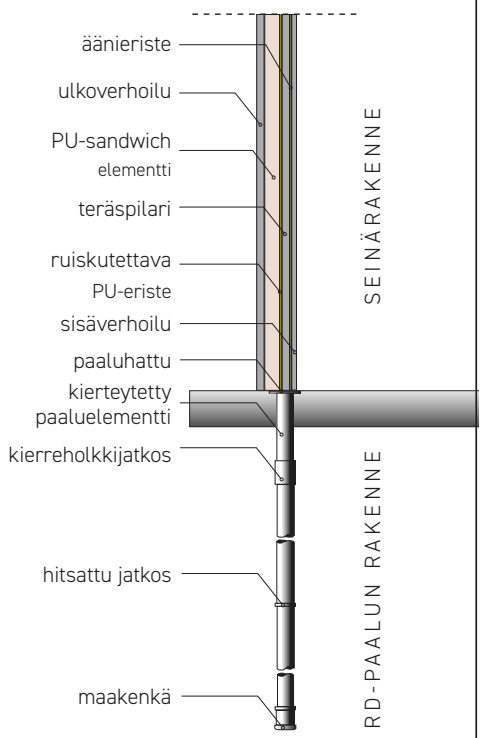
Teräs on erittäin kestävä ja luja rakennusmateriaali. MinunLOFT käyttää rakenteissa palosuojattua ja pintakäsiteltyä S 355 terästä. MinunLOFT-talot rakennetaan CE 1090 sertifikaatin mukaisesti. Teräsrunko mallinnetaan 3D-suunnitteluohjelmalla. Tehokas valvonta ja ensiluokkainen laatu ovat ehdoton osa rakentamista. Asennuksessa ja valmistuksessa OHAS 18001 työturvallisuussertifikaatti takaa turvallisen projektitoteutuksen alusta loppuun.

SEINÄRAKENNE JA RD-PAALUPOHJA



MODUULIRAKENTAMINEN

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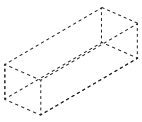

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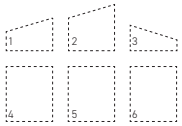

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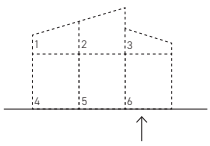

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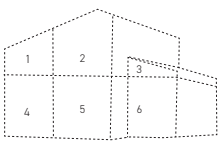

MINUNLOFT

RAKENTAMISEN EDUT:

TEHDASVALMISTUS

PIENET MATERIAALIHÄVIÖT

PUHDAS SISÄILMA

ENERGIATEHOKAS

AVAIMET KÄTEEN

RÄÄTÄLÖINTI

NOPEUS

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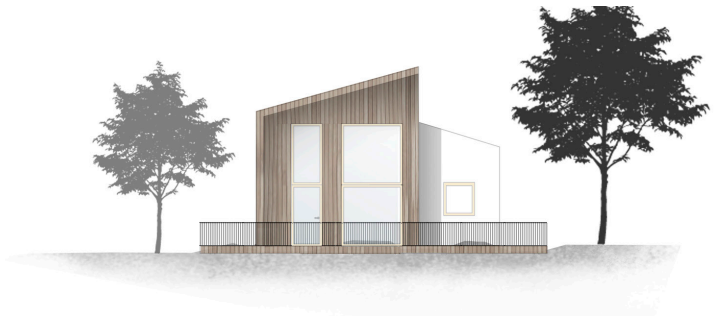
JULKISIVUT

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ILMAVA

Ilmava on moderni
riippuen, Loft Ilmav
kattokorkeus on 3.

i harjakattomallinen omakotitalo. Moduulien lukumäärästä
va voidaan tehdä 45-80 neliön kokoisena talopakettina. Olohuoneen
5-5m.

MINUNLOFT

RAKENTAMISEN EDUT:

TEHDASVALMISTUS

PIENET MATERIAALIHÄVIÖT

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AVAIMET KÄTEEN

RÄÄTÄLÖINTI

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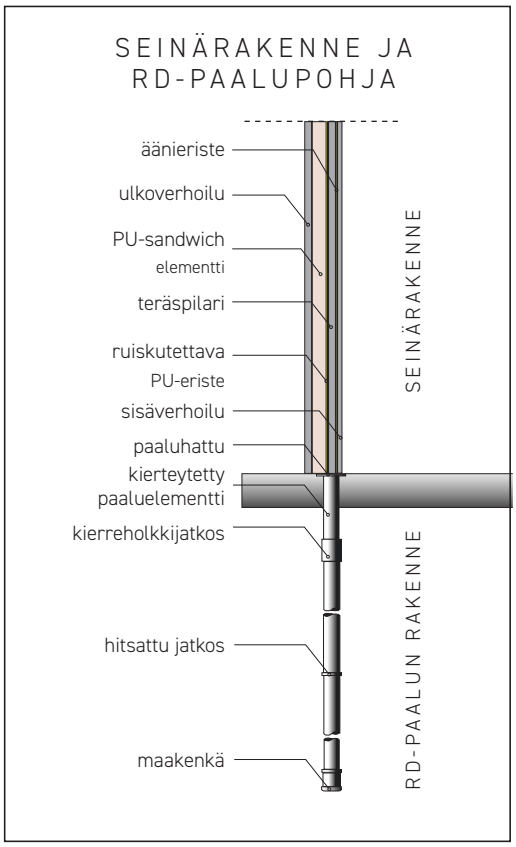

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TEHDASVALMISTUS

Teräsrunkorakenteiset moduulit rakennetaan tehtaassa valmiiksi kokonaisuuksiksi. Tehdasvalmistamiset etuna ovat pienet materiaalihäviöt ja rakennusmateriaalin helpompi kierrätettävyys. Tasaiset työskentelyolosuhteet takaavat rakennustyön laadun on korkealuokkaisuuden. MinunLOFT-koti on ensiluokkaisen laadukas, energiatehokas, kestävä ja terveellinen.

KUSTOMOINTI

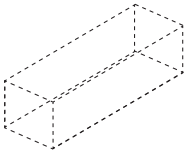
MinunLOFT talomallien pohjapiirustusta ja pinta-materiaaleja voidaan kustomoida asiakkaan toiveiden mukaisesti. Talot tilataan AVAIMET KÄTEEN-periaatteella.

NOPEUS

Rakennushankkeiden riippumattomuus sääolosuhteista mahdollistaa nopean rakentamisen sekä vähentää hankkeen kustannusriskejä. Talomoduulit kuljetetaan tontille ja asennetaan porapaalupohjan päälle. Porapaalupohja mahdollistaa rakentamisen vaikeissakin maaolosuhteissa.

MODUULIRAKENTAMINEN

1. Talot koostuvat tehdasvalmistetuista moduuleista (maksimi mitat: korkeus 4m, leveys 3.5m, pituus 3.5-12m)



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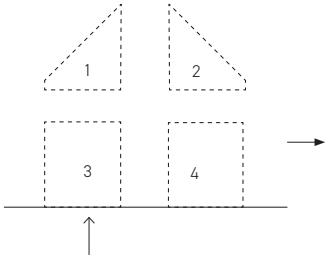

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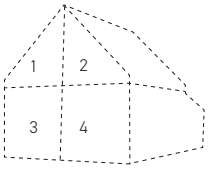
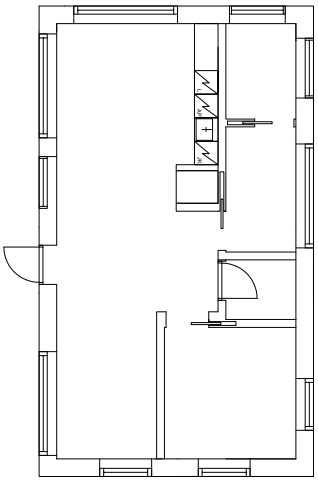


POHJAPIIRUSTUS



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Esimerkkipohja on saunallinen vapaa-ajan asunto, jossa voi majoittua 2-4 henkilöä. Talossa on 70 neliötä ja se koostuu neljästä moduulista. Talon tekniikkamoduuliin kuuluu kaikki vesikytkentää tarvitsevat huoneet; keittiö, sauna, kylpyhuone sekä tekninen tila. Makuuhuoneet on sijoitettu talon takaosaan. Keittiö on yhteydessä olohuoneeseen ja ruokailutilaan.

MinunLOFT:n verkkosivuilla voit tutustua tarkemmin esimerkkipohjaan 360 asteen kierroksen avulla.

Varustelutaso: Pintamateriaalit, keittiö, kodinkoneet, portaat,(sauna), LVI-työt, sähkötyöt, lämmitysyksikkö (maalämpö tai muu), data-kytkennät.

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Terve Talo -sertifikaatti täydentää MinunLOFTin teräsrakennustekniikkaa. Seinärakenteemme ei sisällä orgaanisia aineita, mikä ehkäisee mahdollisten kosteus- ja homevaurioiden syntymistä. MinunLOFTin seinärakenne ja talomallien hyvä ilmanvaihtojärjestelmä luovat raikkaan ja puhtaan sisäilman.

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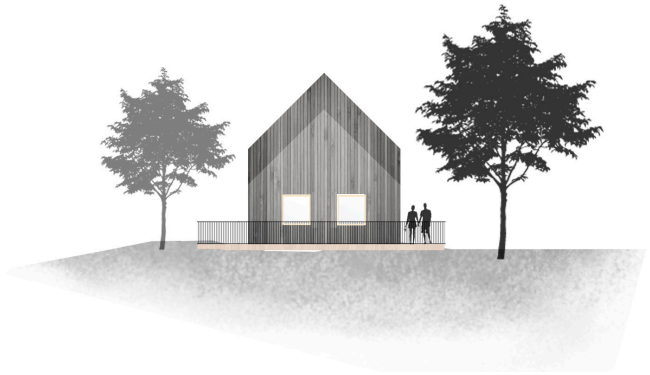
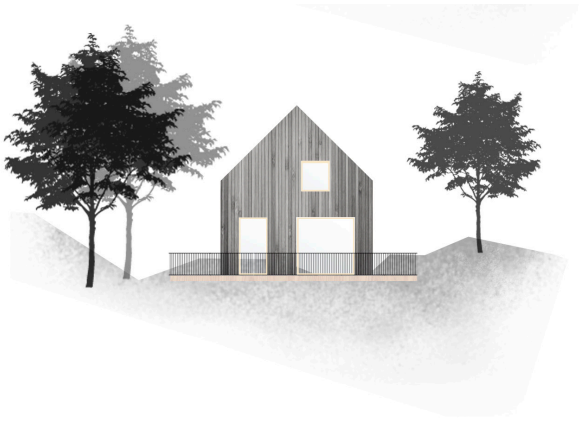
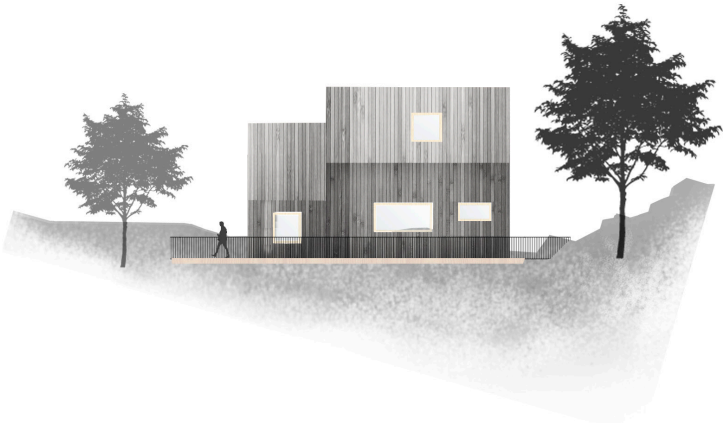
JULKISIVUT







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AVARA

Avara on valoisa ja moderni harjakattomallinen omakotitalo. Moduulien lukumäärästä riippuen, Loft Avara voidaan tehdä 70-150 neliön kokoisena talopakettina. Olohuoneen kattokorkeus on 3.5-7m.

POHJAPIIRUSTUS

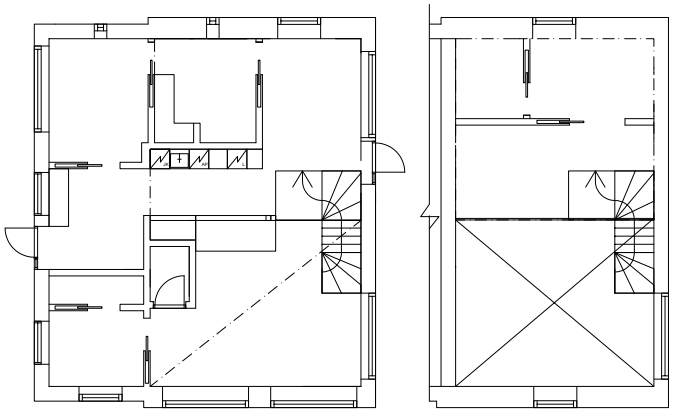
Suunnittele MinunLOFT:n asiantuntijoiden kanssa toiveidesi omakotitaloon sopiva pohjapiirustus ja pintamateriaalit. Voit myös valita talopakettimallin, jossa päätökset ovat tehty puolestasi ja saat nopeasti talomallin toimitettuna tontillesi.

Esimerkkipohja on tehty nelihenkiselle perheelle. Talossa on 150 neliötä ja se koostuu seitsemästä moduulista. Talossa on kolme makuuhuonetta, keittiö, olohuone ja kaksi kylpyhuonetta. Talon tekniikkamoduuli sijaitsee keskellä, johon kuuluu kaikki vesikytkentää tarvitsevat huoneet; keittiö, kylpyhuone sekä tekninen tila. Keittiö on koko talon keskus ja sydän - perhe kokoontuu keittiöön tekemään yhdessä ruokaa ja käymään läpi päivän tapahtumia. Makuuhuoneet on sijoitettu niin, että kaikilla perheenjäsenillä on oma rauha. Alahuoneen olokerta jatkuu yläkerran parvella, joten yläkerran kirjaston nojatuoleista voi silti käydä keskustelua alakerrassa istuvien kanssa.

MinunLOFT:n verkkosivuilla voit tutustua tarkemmin esimerkkipohjaan 360 asteen kierroksen avulla.

Varustelutaso: Pintamateriaalit, keittiö, kodinkoneet, portaat,(sauna), LVI-työt, sähkötyöt, lämmitysyksikkö (maalämpö tai muu), data-kytkennät.

ESIMERKKIPOHJA



ALAKERTA

YLÄKERTA

MINUNLOFT

RAKENTAMISEN EDUT:

TEHDASVALMISTUS

PIENET MATERIAALIHÄVIÖT

PUHDAS SISÄILMA

ENERGIATEHOKAS

AVAIMET KÄTEEN

RÄÄTÄLÖINTI

NOPEUS

TEHDASVALMISTUS

Teräsrunkorakenteiset moduulit rakennetaan tehtaassa valmiiksi kokonaisuuksiksi. Tehdasvalmistamiset etuna ovat pienet materiaalihäviöt ja rakennusmateriaalin helpompi kierrätettävyys. Tasaiset työskentelyolosuhteet takaavat rakennustyön laadun on korkealuokkaisuuden. MinunLOFT-koti on ensiluokkaisen laadukas, energiatehokas, kestävä ja terveellinen.

KUSTOMOINTI

MinunLOFT talomallien pohjapiirustusta ja pinta-materiaaleja voidaan kustomoida asiakkaan toiveiden mukaisesti. Talot tilataan AVAIMET KÄTEEN-periaatteella.

NOPEUS

Rakennushankkeiden riippumattomuus sääolosuhteista mahdollistaa nopean rakentamisen sekä vähentää hankkeen kustannusriskejä. Talomoduulit kuljetetaan tontille ja asennetaan porapaalupohjan päälle. Porapaalupohja mahdollistaa rakentamisen vaikeissakin maaolosuhteissa.

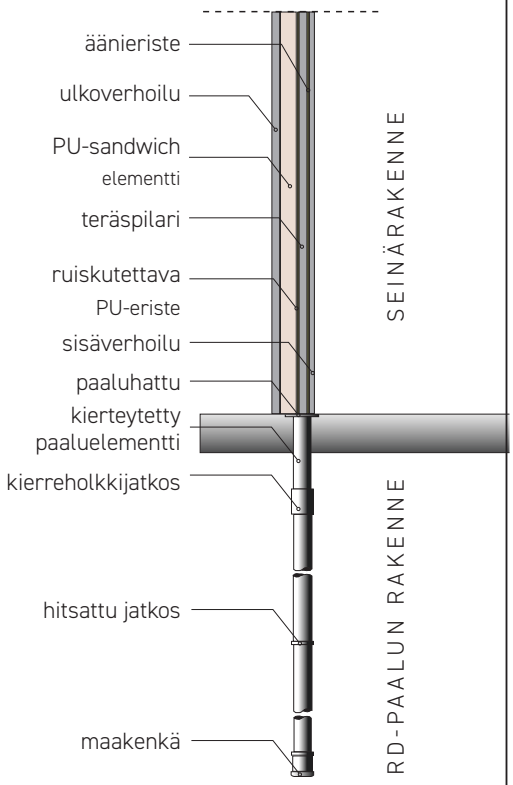
SEINÄRAKENNE

MinunLOFTin moduulien seinärakenteet koostuvat sandwich-kevytelementeistä. Kevytelementit koostuvat polyuretaaniytimestä, jonka molemmin puolin on integroitu pintalevy. Seinärakenne ei sisällä orgaanisia aineita, mikä ehkäisee mahdollisten kosteus- ja homevaurioiden syntymistä. MinunLOFTin seinärakenne ja talomallien hyvä ilmanvaihtojärjestelmä luovat raikkaan ja puhtaan sisäilman.

Polyuretaani-sandwich-kevytelementeillä on mahdollista luoda parempi, lämmöneristys, energiatehokkaat lämmitysratkaisut ja alhaisempi sähkön- ja veden kulutus. Takaamme markkinoiden tehokkaimman U-arvon, eli lämmönläpäisykertoimen ruiskutettavalla polyuretaanilla.

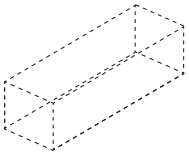
Teräs on erittäin kestävä ja luja rakennusmateriaali. MinunLOFT käyttää rakenteissa palosuojattua ja pintakäsiteltyä S 355 terästä. MinunLOFT-talot rakennetaan CE 1090 sertifikaatin mukaisesti. Teräsrunko mallinnetaan 3D-suunnitteluohjelmalla. Tehokas valvonta ja ensiluokkainen laatu ovat ehdoton osa rakentamista. Asennuksessa ja valmistuksessa OHAS 18001 työturvallisuussertifikaatti takaa turvallisen projektitoteutuksen alusta loppuun.

SEINÄRAKENNE JA RD-PAALUPOHJA



MODUULIRAKENTAMINEN

1. Talot koostuvat tehdasvalmistetuista moduuleista (maksimi mitat: korkeus 4m, leveys 3.5m, pituus 3.5-12m)



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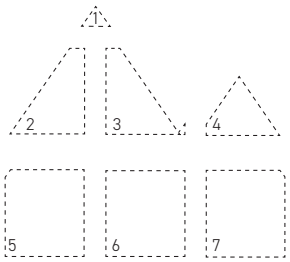
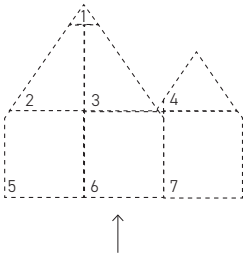
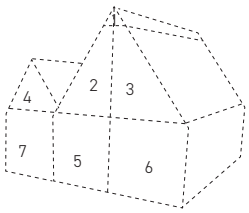


3. Tekniikkamoduuliin vedetään LVI- liitännät sekä yhdistetään mahdollinen maalämpö



4. Moduulit liitetään toisiinsa, jonka jälkeen asukas voi muuttaa sisään. Moduulit on suunniteltu niin, että rakennukseen pystytään lisäämään vaivattomasti extramoduuli jälkeenpäin.



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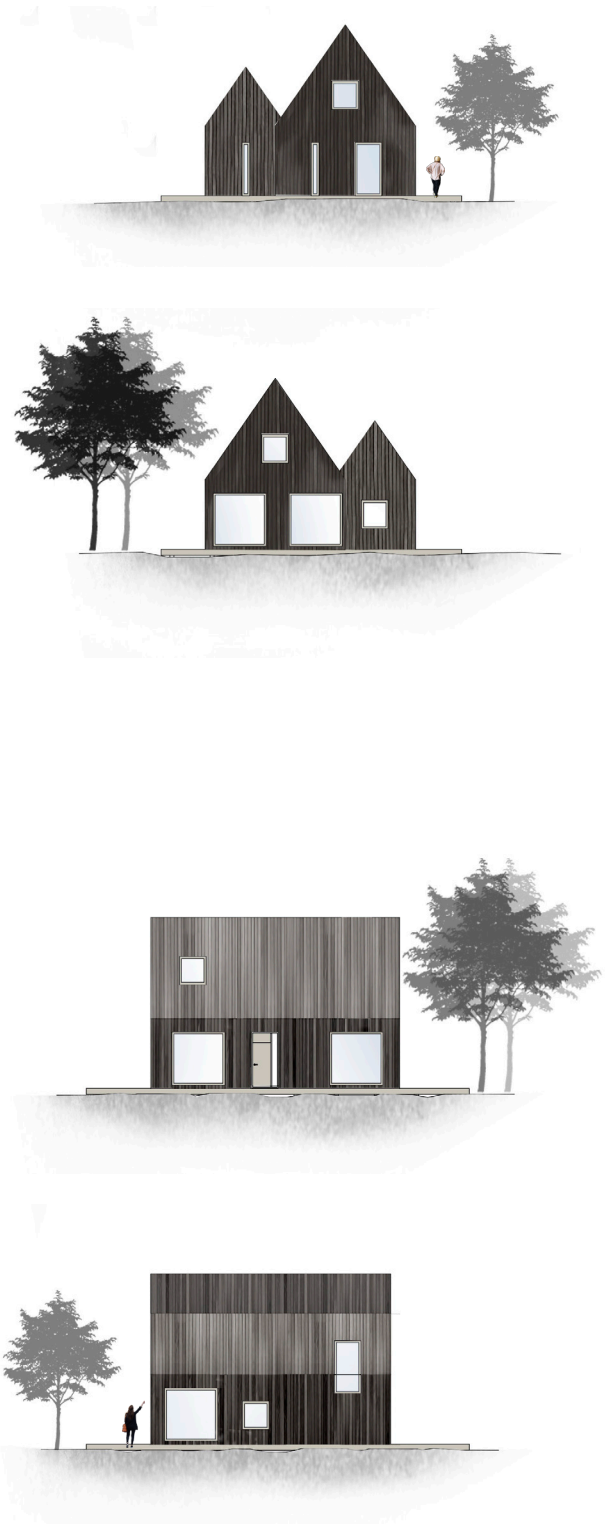
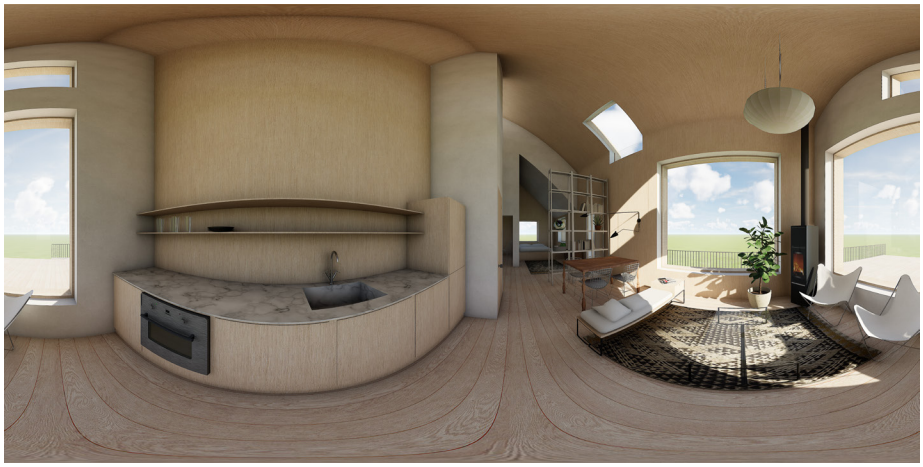


360 TOUR IMAGES



GIVE-AWAY LEAFLET

KOTI

JOKA TEKEE
SINULLE HYVÄÄ

MINUN LOFT

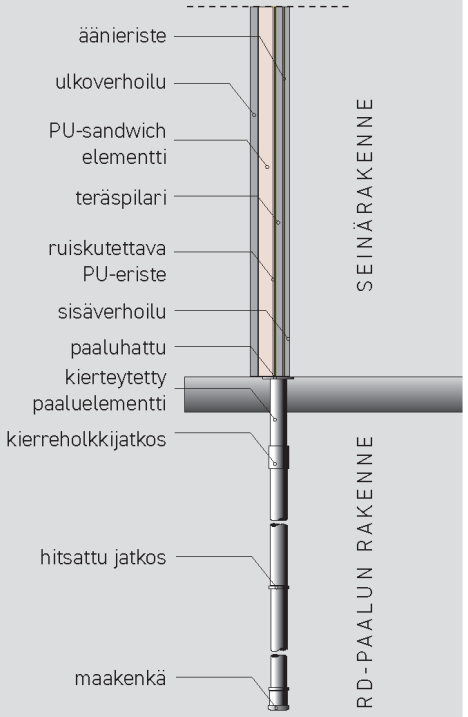
PUHDAS SISÄILMA

ENERGIATEHOKAS RATKAISU

AVAIMET KÄTEEN

NOPEA TOIMITUS

SEINÄRAKENNE JA RD-PAALUPOHJA



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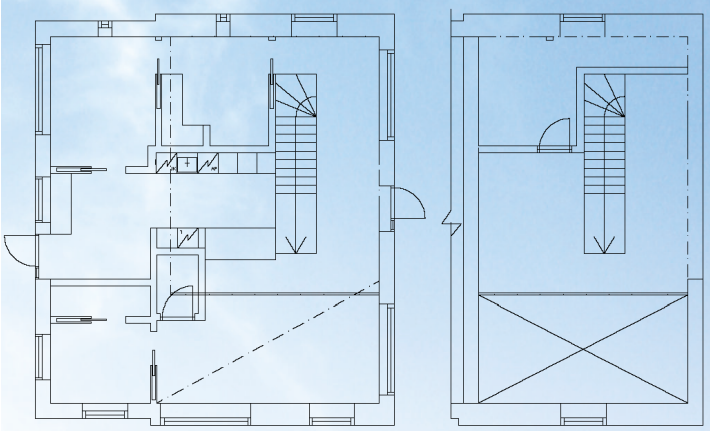
LOFT AVARA: 150 m²

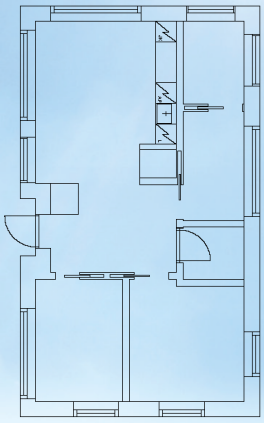
esimerkkipohja: 6 moduulia
3 makuuhuonetta, keittiö, 2 olohuonetta, 2 kylpyhuonetta



ALAKERTA YLÄKERTA

LOFT ILMAVA: 70 m²

esimerkkipohja: 4 moduulia
2 makuuhuonetta, keittiö, olohuone, sauna, kylpyhuone



MODUULIT

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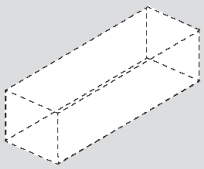

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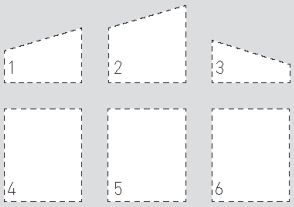

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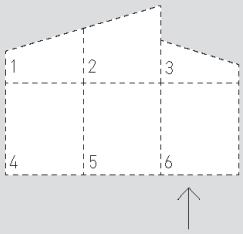

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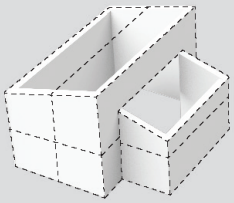
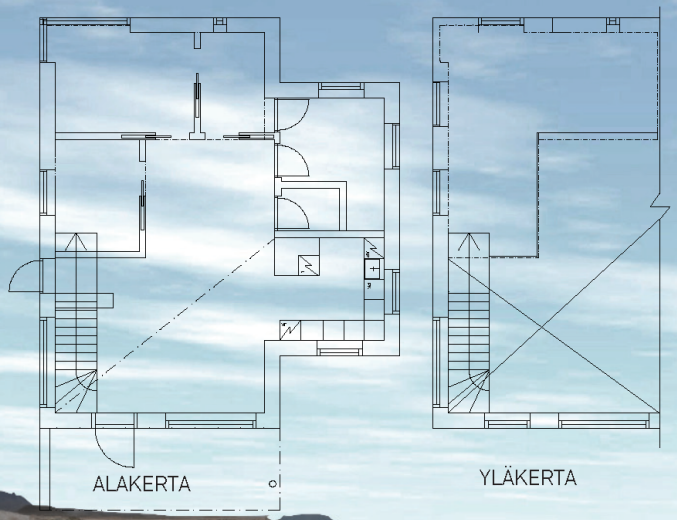


LOFT TILAVA: 110 m²

esimerkkipohja: 6 moduulia
3 makuuhuonetta, keittiö, olohuone, sauna, kylpyhuone



Varustelutaso: Pintamateriaalit, keittiö, kodinkoneet, portaat, sauna, LVI-työt, sähkötyöt, lämmitysyksikkö (maalämpö tai muu), data-kytkennät

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12

CONCLUSION

Image 12. (DiPalma 2016).

12

CONCLUSION

This chapter summarizes the thesis, describes the significance of the findings and gives suggestions for future studies.

The primary purpose of the current study was to determine how professionals were using virtual reality in design work and how VR could help designers improve the design process. The second aim of this study was to investigate the benefits and challenges of VR in design phases. The hypothesis of the study is that virtual reality is a valuable architectural design tool which improves the efficiency and quality of the design work while also effectively aiding clients, constructors, and fellow designers in understanding the creative vision of design work though all phases of a project.

The data was collected with using interviews and observation. The qualitative interviews revealed the subjective perspectives of the designers and the information was broadened with the use of observation. Observation was performed through direct observation in the interviewed companies and unobtrusive observation in VR events. These qualitative methods were selected to describe and understand the use of virtual reality. The learned lessons were taken into practice in the creative project of the thesis.

The interviewed and observed professionals were architects, designers, visual effect artists and entrepreneurs who have worked with VR for years as a tool to create spatial experiences. The thesis focuses on analyzing the utilization and adoption of VR in two architecture studios, Gensler and TCA Architects. The two companies have differences in their sizes, number of employees and resources. Both companies have been working with VR and could be referred as early adopters of the technology. Additional interviews were performed with entertainment industry and VR studio professionals.

The most obvious finding to emerge from this study is that VR has been used as an additional new design tool to help, improve and streamline the design processes. The adoption of VR in design studios has required time, resources, money and the support and encouragement of the designers and the management. The appeal of VR is driven by answering the demands of the clients, improving the technological capabilities of the company, improving the collaboration, design processes and the quality of the design. It is a competitive tool for sales and attracting new clients.

This study has identified that VR can be a utilized in all of the design phases. VR can save money and time by creating a more efficient process for design iteration that allows for thorough design review before commencing construction. This helps to reduce risks in project errors and also allows for an increased insurance of client satisfaction by allowing the client to review the project in a manner that more accurately reflects the final design. VR is helping to make design decisions, discover design mistakes, comprehend the relations of the spaces and allow designers to prototype their designs in full scale. VR has given a new tool to express, reflect, represent, market and sell the design. Overall, this study strengthens the idea that the use of VR has improved the collaboration between clients, designers and the project team.

Diverse challenges in using VR in design were reported such as motion sickness, lack of control and organizational challenges. The research has shown that VR content requires new techniques in order to deliver the design concept and story for the client. Multiple different software and hardware options are a available for VR. However, improvements in both areas are required in order to reach the critical mass of designers in the adoption of the technology. The results of this investigation show that the architecture and design industries may experience a vast change in the future due to VR. While the uncertainty of the future development in architecture can fuel anxiety, virtual reality in design can provide more diverse job opportunities for the designers.

The study results provide further support for the hypothesis that VR is a tool that is currently utilized in the architectural industry as well as other design professions. The collaboration between professionals and clients has streamlined and improved the design process.

The principal theoretical implication of this study is that professional services are one of the primary market segments for VR. The findings of this investigation complement the earlier study of Whyte (2007) who has described the practical use of VR in the design of built environment. With respect to the first research question, it was found that Whyte (2007) confirms the findings of the benefits of VR in design and construction such as developing technical competence, streamlining design reviews, simulating dynamic operations, coordinating detail design, scheduling construction and marketing. Whyte's (2007) findings of challenges in VR are consistent with the findings of the study regarding the control of the design, showing too much, overwhelming the user and organizational problems such as creating rules and structure. The current study did not record the issues of distorted reality or navigation. In addition to this, the findings of the current study do not support Whyte's (2007) findings of economic challenges. It seems possible that these results are due to the advancements of VR technology which present VR as an economically beneficial tool.

In contrast to Whyte's (2007) findings, instead of choosing one strategy of outsourcing, having a technical department or choosing to use a project-based scenario, in this study architecture companies used all of the three different model creation scenarios simultaneously. This rather contradictory result may be due to the technological development of VR software and hardware. VR has become more straightforward to use and it has provided more independence for the designers.

A strong relationship between benefits and challenges regarding the adoption of a new technology has been reported in the literature. Roger's (1995) theory regarding the attributes of innovation, technology's diffusion in society and innovativeness and adopter categories are included to provide a theoretical framing for the diffusion process in architecture companies. In this thesis, however, Roger's (1997) estimated practical adoption rates of the technology in the design industry couldn't be identified due to limited amount of data available on the actual use of VR in design companies. The thesis presents the studies of Sketchfab, Vizpark, CGArchitects that express the quantitative data of the VR usage in architectural visualization. However, this data does not represent the overall use of VR in the industry because the focus groups of the surveys were consisted of technologically oriented professionals.

The present study provides additional evidence for the use of VR software and creating VR content with respect to Hale and Stanney (2016) about the general usability requirements, spatial requirements and nine variables of a VR experience. The findings indicate that VR models for marketing and design differ, which corroborates Whyte's (2007) theory of attributes for the project team and for wider involvement. IDC and Super data have provided the future revenue forecasts to further support the fact, that the architecture and design industries will benefit from the adoption of VR.

The artistic component in the thesis is the design of three loft houses for MinunLOFT. The design development phase was focused on utilizing VR with the intent of improving design results. These experiments confirmed the hypothesis, despite requiring time and effort to comprehend the technology's capabilities. Keeping a journal of the concurrent design process did not produce any novel findings. A possible explanation for this might be that reflecting the process while using a versatile and immersive tool is challenging. Therefore, processing time is needed to recognize the challenges and benefits in the design process while using VR.

Since the study was limited to the VR utilization and adoption of designers in 2017, the generalizability of these results is subject to certain limitations. The focus group of the research was designers who were using or intrigued by the use of VR. However, the designers who were struggling with or had no interest in the technology were not included in the study. Secondly, since Europe and USA are the highest users of VR and the study was performed in these continents, the findings don't represent the worldwide state of how VR is used in the design industry. Thirdly, as VR technology and its adoption are still developing, the results of this thesis are bound to the current state of the technology and societal understanding and acceptance of the technology at the time at which it is written. Fourthly, the major limitation of this study is the used heuristic method, which limits the replicability of the study.

The findings of this thesis bring value for both practical and academical fields of design. These findings suggest several courses of action for architecture and design studios to start the diffusion of the technology. The findings of this study have a number of practical implications and reveal a large selection of software and technology that studios are currently using. Therefore, the information of this study can bring value to design practitioners and students on how to start the adoption process. The surprising finding of the needed creative reflection process time might be a valuable finding in general for research methodology in design. The identification and visualization of the design phases with VR proposed in this thesis can bring new knowledge for both research and practice.

Further experimental investigations are needed to estimate the current level of VR adoption in architecture studios, and the impact of VR utilization in these studios. Further research is needed on the impact of VR on the collaboration of project teams and how VR will affect the changing role of the designers. The design phases with VR should be investigated in a wider context. Due to the ongoing advancements in virtual reality technology, further research is needed to follow the changes of the industry and future design applications.

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APPENDIX

Appendix 1. Gensler, interview on the 16th of June 2017

INTERVIEW QUESTIONS:

SKYPE - LOS ANGELES / HOUSTON

Open ended interview

Name and (title): Interviewee A (Associate, Director of Visualization)

Firm: Gensler

Background: Media Arts and Animation Bachelor (2007). Focused on lighting and rendering techniques. Art Institute Houston.

Technology and Software: 3DS Max, V-Ray, Adobe Photoshop, Substance Designer, Unity – Gaming Plat-forms, Augmented Reality, Virtual Reality, Any others?

1. Is it possible to record this interview?
2. You took a class of Architectural Visualization when you studied in the Art Institute of Houston, is there any lesson from that course that is still good today?
3. Was there any knowledge or thought about VR back then?
4. When did you first try VR?
5. How did you start to work with VR?
6. VR can be a good sales tool for the architects, clients and construction companies, but I have framed my thesis to be about the design in the VR. Covering everything from the clients perspective to the sales to the end customer could make the research portion quite overwhelming. How much has the design process changed in Gensler now that there is this new tool that you can use for the designers?
7. When the VR and AR was introduced the possibilities of VR and AR in Gensler, how did the architects and designers take it?
8. You mentioned in the interview (Gensler's website) that when you were a Visualization Artist in Gensler you were working with the architects and clients in real-time and you are still currently doing one on one project consulting. Are you doing these kinds of design iterations still with the designers?
9. How much do you normally work with Designers and Architects nowadays?
10. How much work do the architects and designers do in VR currently in Gensler?
11. How quickly do the designers start to use the VR in a project, from the beginning / contest phase? Later in the project?
12. Do they only evaluate the projects or do they use it as a design tool?
13. What kind of feedback have you heard from the designers?
14. Has VR/AR made their work easier?
15. What VR system do your designers use?
16. What does VR bring to the designer?
17. Can the designers use VR real-time changes for the design when they have the client review?
18. VR often raises players nausea, what other difficulties have come to the front?
19. Open blank space – does Gensler have it now for VR Designing?
20. 3D sound – simulate sound (acoustics are worked into it)
21. Are the Architects and designers part of the Storyboarding of the VR journey?
22. Is Gensler creating your own software for VR? App Gensler VR already there
23. How do you see the future use of VR and AR in Gensler?
24. In the Podcast that was done in 2015, you mentioned that VR isn't just a still 360 that you can look, that it is more like an Experience – clients perspective not just what you see – sound, interactivity, 360 degree fly-throughs, modulate speed, pause real-time. Do you currently have these options available for the client? *CG garage podcast #38
25. What game engine do you use (Unity / Own)?
26. Do you think that in the future the clients will expect a game-like content in the future?
27. What do you expect from virtual reality? What can it change?
28. How do you see VR and AR in the future? What purposes could it get? How does it change the world we are experiencing?

29. I noticed that there was an SPAR 3D event – AR & VR for Building Projects April 5 – Would you happen to have your lecture material that I could see?

30. You had a course in the Autodesk University 2016 about Substance designer, where you mentioned that you can supply a Handout of the program, do you think it could be helpful for me to use when designing in VR?

31. How much work do you do in Substance Designer?

Interviewer: What is your work title? Is it the Director of Visualization?

Interviewee A: That's one of my many titles. We do titles very weird over here in Gensler. But I also go by firm-wide creative media manager. We define creative media as is anything that falls under rendering technologies, virtual reality, augmented reality, film, some photography, not necessarily like some of the marking photography would do for projects but photography around like photogrammetry. And even then motion graphics and other things like that. So if any application or sort of technologies sort of falls under any of that that's usually under my purview at the firm.

Interviewer: [00:01:30] Based on the technology and software, I guess you have like a huge list of all the software you currently using, but in relation to VR what are the software you're using right now?

Interviewee A: [00:01:46] There's still even a lot in that regards. But I can give you I can give you a quick rundown. So our main design platforms here at the firm are Rhino, Sketchup and 3D Studio Max. So kind of the major heavy hitters there. Our primary rendering engine of choice is V-ray. We integrate V-Ray across all four of those applications and so that in and of itself lets any designer at any time do ray tracing rendering but also that V-Ray makes virtual reality rendering extremely easy. In about 2 clicks and maybe an hour someone can render out a Virtual Reality Rendering at any point in the project. OK so that's one bit of flexibility that we wanted to give our designers and a lot of these tools and a lot of these work flows. Essentially that was our goal we wanted to make it as easy as possible and disseminate it to everyone as much as we could. I was like how fast you get and we are like we wanted people just getting into it using it as a design tool. And so we were heavily focused on applications that would allow us to do just that. And some are easy some are not. It really kind of depends on the projects needs the clients needs what the designer is comfortable using so we kind of had a wide range of tools which is kind of why we have maybe more than what some other firms would use.

Interviewee A: [00:03:12] So with that we use both unity and unreal as our gaming platform. We still use but we tend to lean a little more on the unity side mainly because its easier for us to develop our own applications around because it uses C# versus C++ and also all the augmented reality work that we do is pretty much only supported in unity. So all a Hololens work or the [00:03:38] Beta? [0.3] work that we're doing can only be done in unity. So we leave a little more towards the unity end but we also still have quite a few people that like using that unreal. Since Unreal is pretty much free, we don't we really don't deny anyone using it it's like they want to use it they can in terms of now kind of streamlining some other vr processes: The two other like what I like to call one-click-solutions because that's kind of what they are. We use a lot of Enscape for Revit and Sketchup.

Interviewer: [00:04:08] Okay, that is a new program for me.

Interviewee A: [00:04:09] Essentially what that does is it just translates the model into a game engine like environment that users can quickly maneuver around do a walk through put a headset on and say send me to VR and they do on and actually puts them into a virtual reality space with like Oculus or an HTC. So kind of something really streamlined. You know the visual fidelity is actually really nice for what it does provide but you know the ray trace engines like the V-Ray kind of like seal the deal at the end. You can do something really quick and dirty and get your idea across. Then you can it render it really nicely with V-Ray. So it's it works out real well for us.

Interviewee A: [00:04:49] Another one we've been using very similar to an Enscape is called Fuzor. That's made by a company called Kalloc studios and that one pretty much links with Revit and has sort of a bi-directional wink with Revit, so you can actually edit in Fuzor and push it back to Revit, which is like one of the only VR applications I know, that actually can do that. One reason that we really like user is we can do collaborative VR so we can now bring in multiple designers or multiple clients, not only in the same office but across the world, so we can actually set up sort of like a multiplayer server with that and bring in people from all over.

Interviewee A: [00:05:36] So every Wednesday afternoon we actually do something in the firm called VR. Jam where we feature a project that everyone can do like a virtual tour of the projects using Fuzor and VR. It has been actually really fantastic. It's completely blown up. It's started as just a small little thing happening in our LA. and Newport office and that it grew just tremendously from there. Everyone started jumping and I think we get about like 22 offices participate now which is about half the firm which is pretty pretty substantial. If you think about it. So we like that application a lot. In fact, Fuzor is throwing their own little conference today actually down at Newport. We have some of our colleagues down there presenting. I was actually just on the phone with them. Everything down there is going really well. So that's good. And then there are a lot of other little ones that we play with there's one called Twin motion which again is kind of like sort of the Fuzor and the Enscape. We look at Iris VR, Insight VR, [00:06:44] YULIO, [1.6] Clever is another one. Clever is not so much VR though but they do they have a really interesting platform and they've been integrating with Chaos group a lot lately. That's one reason why we've kept an eye on them because that may be that may prove valuable to us in the future. But even then what they currently offer is still really nice but it's more like a 3D presentation than it is virtual reality.

Interviewee A: [00:07:16] In terms of in terms of our VR suite that's kind of it. Two other applications we use to help augment that as we set up a render farm around the world with an application called Deadline. So we at least have a global rendering farm that any user can tap into to help with the rendering portion of that. [00:07:36] And then we use another application called Substance designer. [00:07:51] We use them to help make our materials from all the renderings which is a huge help. [00:08:02] Yeah the learning curve is a little steep but if you can get over it it's so worth it. It's one of my favorite applications right now. It's a stand alone app so you can make you make the texture inside of Substance Designer and then from there you can package into a substance file and you can click and drag it right into unity or Unreal or you can export out the appropriate bitmaps for like V-Ray or wherever you really want to go. And so essentially what we do is we can make the material once and then have it the same in every single application that we're using.

Interviewer [00:08:53] I'm interested in how you get to know the VR system and how did you introduce it to the company?

Interviewee A: [00:09:07] I got to think back a little bit on that because it actually was a while ago. For the longest time so you probably know my background. I don't have an architecture background. I studied illustration and film and photography. Technology has always has been I thing of mine and so a couple of years ago and I want to say this is probably back in 2009. Unity just went to version 3 and 3.5 and so I started looking at that as like what would be really cool if I could take one of our projects and create sort of like a video-game-type-experience around it that we could just walk around interactive stuff. And this is well before VR was even a thing. But so this was just like on an iPad or on my computer we could do this, right.

Interviewee A: [00:09:53] Kind of sold it to the firm a little bit. But really the work flow around it. Still took a lot of time to kind of get up and running. It would probably be only ideally to use it on very larger projects that have a very extreme budget that doing that kind of work isn't a problem. So we kind of tabled it but I always kind of kept in the corner of my eye and played with it at home when I had some

downtime and all that. And then when unity 5 came out about two or three years ago now along with Unreal going free. They they both went at the same time, it is really interesting. We sort of revisited it. Let's take a look at the game engine again because now the lighting and the materials look even better than they did. Seemed like the workload is getting a little more streamlined and it was still a little bit hesitant you know our designers they're really hesitant and careful about introducing new things into a work flow that to them already works and it's working for years and so it's like why do I need this new technology. Right? It's usually the first thing that I get asked right.

Interviewee A: [00:11:06] And you try to make the case of like oh it's going to save us time here, there, you know it's different, it's cutting edge. But then VR started to come in and now we started looking out like the Oculus DK 1, DK 2, okay, what can this really do and that's about the time where Chaos group introduced the VR rendering formats in 3D Studio Max. And so then we started doing these spherical renderings in stereoscopic and was able to load them into some applications and get these really cool renderings. And that's sort of where it really started to kick off for us because first then you get the again the designers like oh that sounds gimmicky like why would I do that.

Interviewee A: [00:11:52] And so usually what I would do is I would say OK what's your latest project send it to me. Give me three days. I am going to do some renderings and then I'm going to show you why this is important. It it's no more than putting someone in VR with their own project for that light bulb to go off. Right. And as soon as I did it it's like finding one that one of them told me buy me 10 of these units right now. [00:12:15] He didn't even care what the cost was. Just buy it, you know. That's that's sort of how we started to push it out in the firm really was just kind of like showing it to people. And even then sometimes our clients came to us asking for it. So even as we're trying to get the word out and we're for very large firm so sometimes communicating this information is actually rather difficult. You think it may not. It's it really is sometimes. And so it's like you get one off it's like LA. All of a sudden like they just go gungho with it like. All right we're doing this and then but even in even in that office all of a sudden one of their clients comes to a principal is like we never hear about this VR thing can you do that and then you're like oh I don't know can we do.

Interviewee A: [00:13:05] Virtual reality solves this communication problem that architects and clients have. And even then sometimes that even designers themselves have within themselves because we're so used to working on a flat screen. Right. And a like a just a 3-D viewport either an isometric or a perspective view but you never get that sense of what a debt ceiling in a space feels like. Right. Like you're just playing around and since you're eyeballing it in a sense is like oh that looks good right. Yeah. But you don't know. And so that's where virtual reality comes in and solves that problem which is actually a big one because if you can solve that problem very early on in the design phase things become much easier further down the line. And it's also a reassurance to for not only the designer but for the client that what we're building and what it feels like is actually going to be what they get. And we're starting to realize that now that some of our early projects that used VR now starting to come to completion that it is actually really the case. That's that's really happening which is really exciting to see. Like you I put this in, sadly some of our projects are like three or four years long, so you don't really think it's until later which is also an issue we've had in terms of doing a lot of these presentations because we're doing VR and all these projects right now. But since it's still we're all "relatively new" we can't talk about it because we're under NDA for all these projects.

Interviewee A: [00:14:49] And it's funny because all these publications want to you know come to us. We do these interviews and they need images and I'm like yeah I can get you any. That will change in the next the next probably a year or two will finally will start sharing a little more of that. But that's what we learned really on this like that A. It helped in the early and design process for designers to look at their stuff which is one way one of the reasons why we decided that we needed to make VR accessible to everyone because even if you're not used to doing visualization work or any of this it's like we still wanted to have that designer be able to go you know what I want to look at this and VR and then let me just click this button and do that right. That's all it needs to do. It doesn't need to be too flash at that point he's not going to care. It's like, let me just see this right. So that's been huge. And then on the client side. You know we have a lot of clients who have a hard time understanding like 2-D plans and even renderings sometimes. They look at the rendering like I get it but I'm not feeling it.

Interviewee A: [00:16:07] And so it's funny. We we've even noticed that when we present VR and if you're going to do a presentation this is maybe a good note. Always do VR at the end of the presentation. It will completely sidetrack your entire presentation if you start with it. It's going to get derailed immediately. So if you have other things to talk about or to show you can always do that first and then you end with VR because then you've talked about what you've wanted to talk about. Now you can kind of hassle them a little bit. But we had a client actually two clients that this is when we realized this is really going to be really important to us is that we were working with the Los Angeles football club stadium that's going up outside of Downtown LA. They were having a hard time deciding where they wanted to put the big LED scoreboard. Kind of a big deal in a stadium right. Like where does that go on plan. You couldn't really tell if it wasn't going to be a good location or not. Some of the renderings again it was kind of like kind of like it there. But I don't know. Right. And so what we ended up doing is we put the scoreboard in every location we thought would be good. And then we did a series of 360 our VR renderings from multiple spots around the stadium so we did it like center pitch. We did a couple of places to the stands. We did it on the catwalk. We did it in the president's box.

Interviewee A: [00:17:35] And then essentially set the client down and had him swipe through all the different renderings and he was like: "I want that one." And we had about ten minutes we got our answer. You know they were doing all these presentations and all this time to put together this package of having him and none of that worked. But within 10 minutes we're just doing like six VR renderings that he made one of the biggest design choices of the stadium right. Yeah. So that's one when you know light bulb moment for us. Oh. OK. And then we had another company. It was a much smaller one who was doing a restaurant and they just weren't getting any of the Sketchup renderings they were doing very simple renderings because the budget wasn't huge. Most restaurant budgets aren't. And so I quickly on the side did a one or two VR renderings for them. Really simple and conceptual nothing and nothing super photographic but it was enough that when they put the headset it was like: "Oh I understand what you're doing here now. I like it. Let's do this." And again it was just more of that like immediate feedback of getting that decision made. Which they were spending again hours on a burning fee. Right? And so now the little work I did in the 10 minute meeting I mean that was a small fraction of the cost that they put into trying to do all this.

Interviewer: [00:18:54] How much are the architects and the designers using the VR in their daily work?

Interviewee A: [00:19:10] Quite a bit. Maybe not nearly as much as I would like yet only because A. I still think it's relatively new to a lot of people. And so there's still that hesitation of like I know I have X amount of money to get this done in X amount of time and I don't want to introduce something new into my work flow because I don't want that to become like a rabbit hole and burn fee. So there's still some of that going on. That's just a slow barrier that has to be broken down over time. That's just not something you can force on anyone. But the more and more VR we're doing the more VR is out there trending online and in the news, more and more people are indeed opening up to it. And so now we're creating like dedicated VR rooms in all of our offices. You know I mean it's definitely getting there. And so for the most part some offices now add in one VR rendering for every project as a minimum just as a that's just something we're going to do OK for the client. Now in terms of the design process that's really up to the project designers using it and there are quite a few who are jumping into like an Enscape for instance because it's so easy to get in there right and so more and more and more people are finally jumping in because that barrier to entry has been brought really low and the hardware isn't necessarily that expensive. And you know the firms are really putting some major investment behind it now. It's just becoming easier. So I wish I had like a good statistic like half of all projects are in VR now. It's really hard for us to do that.

Interviewer: [00:20:51] So depends on the designer?

Interviewee A: [00:20:55] It does but I would say there are a very good handful of people who are using VR to their advantage in the design process at the firm. In fact to the point where I am I now host a weekly meeting around just VR in the firm so people can get together show off projects or talk about issues or you know just to keep that communication open because again we are such a big firm and you know I pull in about 30 people every Friday on that call which is actually pretty good for a webinar at the firm yes. So essentially a weekly one

and a lot of people were like they like that being on Friday because it's kind of fun to talk about this stuff and they can relax a little bit. So it is quite a bit like that. And I don't think it's anything that's ever going to go away or slow down. Yeah I mean maybe in entertainment like I know entertainment still really trying to find its footing in virtual reality. I've seen some interesting short films but nothing that has been like you couldn't have made that in a typical film format or even like video games for instance. There's just not that thing yet. They're getting there. But if TV entertainment was just flat out failed tomorrow or people are just abandoning it, I think designers would not jump on that bandwagon. VR is going to stick around here. It could fail everywhere else but I really feel like VR is finding its home in design and in enterprise level areas. Which is strange because all the venture capitalism went to the gaming side and the entertainment. Where it's like, guys you probably actually should have flip flopped that and put all your money into developing. So I was just going interesting to see that. But. Yeah there's quite a few of us and so there are a lot of projects doing that.

Interviewer: [00:22:48] Do you use VR to show options for the client, etc walls, colors?

Interviewee A: [00:23:06] Yes. One one of our best case studies right now that is still confidential, I can kind of talk about it, but is we have a hotel client out of our Chicago office that we're working very closely with. For hotel rooms and hospitality design what is a very big common practice is that we design something and then we physically build the entire room. OK. So the entire hotel gets built in warehouse. And then the client comes in it takes a look at it in space like they would really build it and then they would usually make comments like I don't like this carpet and I don't like this furniture. I don't like this all like that or I like this. We've replaced this client has replaced a lot of that with doing VR now. And so what we end up doing is we end up modeling all the options we can possibly think of. Right. And we put them into a VR space the HTC Vive. The client can then walk around with the HTC by walk around the hotel room in VR and take a look at it now. It's not going to replace the physical mock-up part but we still need to do that, because essentially for hospitality you really need that tactile feel on and all that. But when it comes down to like picking furniture design or just certain finishes and color schemes and things like that you don't really need to build the entire room. So what the client wants to do is or we are doing now is we show them everything in VR first and then they only build the physical mock-ups of the ones they really like. They're really want to see this one built. And so now they are spending like I'm going to throw a number out there may not be accurate but let's say $500000 on mock ups, right now they're spending a quarter of that or less. OK. That's huge savings. OK. So it kind of goes the same thing with like building physical models of projects that still it's a very expensive practice to build a really nice physical model. I don't think that's going to go away but these technologies are helping augment the cost of that because you can save that part until the very end when you want a nice showpiece or something. Instead of having to spend all that time and money during the design process of building this physical model over and over and over again which can get really costly. You can do that all in VR. And that's actually the physical model part is where augmented reality really plays a huge help. We'd like to Hololense for instance but we're learning that like just VR and AR are saving a lot of time and money in certain areas like this where it's like where we used to spend a lot of money physically building it we're now it's like we can cut that at least in half doing some mock-ups and be our first.

Interviewer: [00:25:58] How do the dedicated VR spaces work?

Interviewee A: [00:26:24] We treat them much like conference rooms. And so designers will go ahead and check them out to use the equipment and they will either use it for their design review or if are going to have a client meeting. It'll be a nice space to bring the client in and do the presentations for. So they're committed dual purpose. And that's really only for the HTC Vive. The IT keeps them and then designers can check them out like we do cameras or other equipment for an extended period of time to do their presentations or reviews or anything like that. And a lot are a lot of our major offices have quite a few of those on hand because they're so they're relatively cheap and everyone is doing like the 360 renderings out of the V-Ray and other applications that having quite a few on hand has been really helpful because they're checked out like all the time. So yeah and you utilize quite a bit.

Interviewer: [00:27:41] Have you heard any feedback from the designers that they are experiences some motion sickness?

Interviewee A: [00:27:44] Yes. The 360 renderings for the most part on a gear VR or like a Google cardboard device you pretty much don't get that because it's a static image you can't really move around it. And so there's two there's two instances where motion sickness gets introduced into virtual reality. One is when the VR camera or environment is moving and you are not. Then your brain knows you're not moving but it sees you are not moving and so your brain has is disjoint and that's when motion sickness comes into play. This is why I'm not a huge fan of like VR animations and video. It's for that reason. Unless it's like your you can realize that you're like sitting down or you yourself are not moving in the environment is moving around you. That's OK. But if it's like. If it's other than a like a roller coaster if it's anything else for the most part your brain freaks out. Especially if some one else is controlling you. Then you're really done. The other part is who is then when the hardware can't meet the frame rate properly for VR. So the recommended is like 90 frames a second per eye. If you can't meet that for the most part that's when motion sickness starts getting into play. Now I've at least for me in a lot of people that I have done the demos with I find like the 60 70 range is still OK. If you drop down into the 30 range then that's where it really starts to become a problem. Well we as a rule of thumb try to target 90 as best we can when we're developing like unity or unreal. And we've been we've been working closely internally on creating tools to help with that and also working with other companies to help with that too because it is it is a problem. But for the most part we are pretty careful about optimizing our scenes as best we can for that because the last thing we want to do is make client sick. So it's pretty much been a rule of thumb that if your demo isn't acting, you just kind of scrap it. It's better not to have VR than to have VR and make the CEO of a company sick. You don't really want to do that.

Interviewer: [00:30:16] Do you think that in the future the designers have to have kind of a storyboard for the presentation when they show the design for the client?

Interviewee A: [00:30:32] Oh yeah most definitely. In fact I think we're already starting to see that much like how we handle 2-D PowerPoint or PDF style presentations. We're now starting to see that trickle into our VR experiences. We want to start now here in the lobby and we want to take them through here and look at this and look at that. I mean it's a pretty easy jump but you do have to realize that there's just a lot more information to consider because the client could essentially look anywhere or depending on how you build it you go anywhere. Yeah. So there's still some things to be learned there but I think you know we already look at storytelling from the beginning of a project anyways and so it was a pretty natural fit to be like okay well how do we tell a story here now. Right. And I always like to tell people it's like you don't some traditional storytelling methods kind of like storyboards for the most part , don't they work but they don't work like they used to, were traditionally do you have to look at it like setting up of our experiences exactly as how you would want to experience it in person which is a lot different than framing a shot and trying to focus someone's attention on this item or that item or something along those lines. It's a small shift in the mindset but it needs to happen to create something successful.

Interviewer: [00:32:00] I visited the VRLA and heard that a lot of companies are using sound to draw the attention of the person in the VR. How much are you using VR in the presentation?

Interviewee A: [00:32:20] Not nearly as much as I would like. Sound is probably the next big barrier we need to figure out a crack of how we want to do that. Sound get starts to get really tricky in terms of capturing sound that hardware starts to get really expensive. Also if you want to use sound that's already created licensing around sound effects and music and whatnot can also get extremely tricky because there's no sort of set standard around music licensing it's really up to the person who's creating the content on where how and when that can be used. And I've even started to notice now too that some licensing around music is now starting to have a like "game license" or "interactive license" on it because it's a it is a new medium. So I don't know but I know there's a lot of technology going into sound for virtual reality. Nvidia has a SDK called VR works which they create a lot of really cool little tools and plug-ins to help performance of VR. We are we're looking at integrating a lot of those but they just at their latest conference back in April released the beta for their, I don't know the exact name, but it's like the audio works or it's Nvidia audio works or something along those lines. But essentially what they did

is they took their ray tracing technology and essentially applied it to sound because that's essentially what sound does it bounces at one point to another like a ray does. They're looking at being able to simulate sound in a space using their ray trace technology which can get implemented into something like unity or Unreal which then will allow you to create really believable sound effects for VR.

Interviewee A: [00:34:22] Right now you typically get your stereo and your fake I'll call it like a fo-surround-sound in the headphones. But this would really give you the perception of like how sound is bouncing off of a wall or it's really coming.

Interviewer: [00:34:41] Where do you see that the VR is going in architecture and design? What are the next steps? I went to this event where they were talking about mixed reality and how it creates possibilities for all the designers.

Interviewee A: [00:35:16] Yeah you know I don't know if I'm on the mixed reality bandwagon yet. Yeah I really like I. Don't like comparing AR and VR because I feel like they both have two very specific use cases and I don't know if marrying those two use cases is Necessary. Now the way I see mix reality as like augmented reality plus one in a sense. It's more augmented reality that interacts with the environment. So you're still not using virtual reality in the way I like to look at virtual reality is if I want to take you and I want to put you in a place that doesn't exist or a place that you can never go to. Virtual reality is like ideal for that. Right. But if I want to take an environment and put it in our world. So let's say I'm redesigning your window behind you. Right. And I want to show you that in space in place right. That's really where augmented reality comes. The power of that. So it's like now I'm taking the 3-D model and I'm bringing it into our world to interact with us here versus going into another world. And so that's where I like to keep the separation of the two.

Interviewee A: [00:36:40] As where VR is going: Collaboration I think it's going to be the big buzzword this year in terms of what VR can do. After that I think it's going to be designing in VR. So having our applications like Rhino and Sketchup and all that having the ability to put the headset on and then work in those applications in a VR space. I think that's going to be a next logical step.

Interviewer: [00:37:10] The program Tilt brush is so incredible already. And if you were able to do something like that with building and masses. It would allow the designer to actually do everything in the space and seeing everything in.

Interviewer: [00:37:36] You had a lecture about VR. Would I be able to get the lecture material?

Interviewee A: [00:37:53] Yes. I can give you the slides and I went to Venice a couple of weeks ago to present at a conference on VR, and I think I can give you those slides as well. I did a presentation for Chaos group last week in New York that got recorded but I can't hand out some of the content. But that is streaming on Facebook so you can watch that presentation. Let me see I'm going to see if I can find that link.

Interviewer: [00:38:47] Do you have anything else that you would recommend to read?

Interviewee A: [00:39:01] You know I just I read a lot of stuff online. I'm trying to find out trying to get good reading material. I browse a lot of gaming websites honestly because that's where a lot of our tech is living right now. One of my favorites is it's called Level 80 or Elvie 80 com. That's a good one. What was the one? I browse art station a lot which is not necessarily like a news article website but there's just a lot of really good art on there. And so I just go and some people will post how do's on how they made certain things. So I tend to just kind of scour the Internet for stuff like that. There's a Web site called Gum road. I don't know if you're familiar. Some people put some really cool stuff up on there in terms of just techniques and applications and tutorials and stuff. So. Yeah I'm just really trying to think. I feel like I've just been it's just been a lot of trial and error for me honestly. In some of this. Because it's still so new there's not like just a plethora of information but there are a lot of people out there even YouTube is actually really good. You know starting like VR experiments and see what people are doing. Like for instance when I was in when I was in Italy there is a visualization studio called Brick visual out of Holland. These guys were awesome. And they what they did is they created a virtual camera rig in a green screen studio. Using the HTC Vive and the new HTC Vive object tracker. So there's a little tracker thing that you can essentially attach to an object and then you can have it show up as something in a virtual reality and they actually they melted that to the camera. And so as they moved around in the VR space they took the camera coordinates. That the Vive was tracking and inputted them into unity and into 3d-studio max so that they make it take that camera and essentially film an actor in a green screen and take the actual camera movements and turn it into an 3-D animation. It was it was really impressive and it was just kind of like this little tech demo but I was like that's really cool.

Interviewer: [00:41:52] Remedy is doing something like that, they track movements of the actor and the camera shows the animation of how could look in the game.

Interviewee A: [00:42:11] Yes. Yes it's very something similar to that and it's more like the poor man's version of it. But you know it's relatively inexpensive to those camera gears that some of the high end studios are using. HTC themselves, they attached like eight trackers to a person and was able to do motion capture data. So they motion captured like a ballet dancer and they took that information and applied it to a character rig and it was able to animate a character off of the information they got from that which was really cool. Because motion capture rigs are extremely expensive. So to be able to set up like. You know there are some there are some other great conferences coming up. Nvidia's conference just happened and there is some good information there. The next one coming up is would probably be Unity's conference. It's going to be in Austin Texas this year. I know Autodesk university is going to have a very large VR presence this year they had a massive one last year and I can only imagine it's going to be bigger this year. And then the one after that probably to pay attention to is GDC the game developers conference in San Francisco in March. I know this year and I didn't get to go but this year they had a whole VR extra ticket you could buy that got you into like just a whole dedicated track to virtual reality.

Interviewee A: [00:43:55] I'm sure you can start to find a lot of these notes. I know a lot of the like the white stuff and the Autodesk stuff goes up online shortly after the conference is over. And I know same thing with GDC. So even if you don't get to make it to the conferences, give it about a month, you can start looking at their website and finding the videos.

Interviewer: [00:45:38] When the designers use VR, do they get to do changes while they are doing changes?

Interviewee A: [00:46:22] Yeah. Ideally what we want to do is we wanted an designer to handle anything they needed to do themselves. Having to come back to me every time the firm of 5000 people isn't really idealistic I'd never get anything done on my end. Some of the applications are like even the Fuzor in the Enscape have locations or one are reasons why a lot of our designers have gravitated that is because of our easy to do just that. So for instance when a user has an escape open they could actually make a change in Revit and it automatically gets pushed to an escape. There is not a lot of wait time between the applications talking to each other to see that change. Which is huge. And they even start to do that in front of the client and certain presentations. Now its like oh is taking these options real quick follow them on and off. And so. Yeah very much that the designers have the ability to change things on the fly if they need to. Yeah.

Interviewer: [00:47:24] How much did does Gensler develop you own software? I've seen the Gensler VR app. Do have programmers working on in some software?

Interviewee A: [00:47:42] That is something we are really starting to push now. The VR and I sort of came out of Alan and I talking on a Friday one day and he's like you know really cool. If we could just take our own vr renderings and plug him into like unity. Because at that time there weren't a lot of really good solutions to do that. And I was like you know there's no reason why we can't. Let me let me play with something over the weekend that was stopped. And so I mean he's going to be like four or five hours on the weekend and put a small simple concept together. Got it working. I was like yeah we could do this. Yeah. So there's another colleague of mine at my studios, Ian. Even he sort of are at the time our developer. And so I gave it to him and he ran with it. And that's sort of where the VR app is today. But

realizing that's A. We are going to need to develop our own platforms and tools and B. that Ian is one guy. Yeah. We're starting to hire more software developers. And so that's something that not only that I've been preaching for a while but the firm is really starting to open to me. They're like OK to get some of this stuff done. You can't hire a designer to do it. That makes no sense. We need to hire someone with a background in this. So yes.

Interviewee A:[00:49:02] So I would say moving forward hopefully this year and definitely in the next year we're going to start having a lot of our own custom tools and platforms the software is for our designers use.

Interviewer: [00:49:17] Do you know any other design and architecture company's that are currently using the VR in this scale? Because Gensler has the resources to set up a system and any designer in the company can easily start to use VR.

Interviewee A: [00:49:52] Yes and no I don't like to assume our competitors are not doing this because of how easy it is. So I automatically assume everyone is doing what we are to a degree maybe not so much like a lot of a custom development but Enscape is not expensive. So I like to assume everyone's using that right now. But on the flip side I mean I've seen I've seen some other companies like the news showing off some of the VR work here and there that they've done on in an airport or. Wherever. I mean at this point in the game if the if there's a competitor of ours that's not doing VR or they're not going to be around much longer. I have some friends and some other firms and like you know I hear that they're dabbling here and there with it and whatnot. It's really hard to gauge because not everyone wants to be too open about that. But talking to some of my friends out there in the industry in terms of like vendors and third party and Render engines and stuff like they say that we are pretty far along. So it makes me feel good at the end of the day I don't know I don't like to stay complacent with that. I'm not about to go. OK we want and not do anything. But I would I would be hard to imagine that some firms have not fully embraced it and jumped in yet. And we even noticed too that I and it's been even though all this work I've been doing in communication right telling you that how some designers still are like oh can we do that. Right. You know we have had a few issues where we've gone and pitch to a client and have lost because we didn't do VR on the pitch. And a small boutique firm did do it right. So that's sort of also helps drive a lot of it like everyone has to do VR. The firm getting behind investing in all this because it's like when you when you start seeing that happen it's like it's really easy to do why are we not doing it right.

Interviewer: [00:51:52] Do you use VR to show the AI like the movements of crowds?

Interviewee A: [00:51:59] You know not yet but it is something that I really want to do. In. I don't know if we're going to definitely would help add to the experience to some what we have learned though is that the 3D people though don't look all that great. Lot our clients tend to call that fact out. And so sometimes it's easy not to put them in if we do we usually kind of leave them all white. We don't make them look realistic. For that reason they just end up getting distracted by it and then the media doesn't go anywhere. But we know there are a lot of people now, Autodesk being one, who are starting to create simulators for crowds and buildings and even in terms of like how Egress works. Like if you set a fire in the corner building How does everyone react and leave. I don't know if there's an application for VR in that regards unless you kind of want to be in there with the crowd and trying to get out with them maybe. But it's not it's not an avenue we've gone down just yet. But I feel like one when that software starts to come up with more simulation level style work I can't imagine we're not going to look at trying to do VR there to see if there's something I just don't think that other software isn't mature enough yet to provide accurate data or even trying to fit into our work flow at the moment. But I would love to do like you know a shopping mall and have people walking around or if you're doing like a mixed use retail center and you've got the cars driving down the streets and people are crossing at the right time and you know you get that little dog you been off in the corner. Because all that adds to the experience right. And the more you pay the more you can sell that the better off you are.

Interviewer: [00:53:59] I think it adds a lot to the story. And the feel and how the scales work together with people and that's one of the. That kind of videogame-like feel.

Interviewee A: [00:54:19] Exactly. And then I feel like that will start to add more of that narrative, a little more naturally into the project. So then of course I had a run out of my own Playstation because my parents for that. don't even remember how immersive it is to put all that is in this space a you're like every time you're so surprised by the fact. OK. [00:59:20] I don't know if that surprise factor is never going to go away. It's kind of like also a senior project finally completed built. It's a really strange feeling.

Interviewer: [00:59:36] How much do you work with the designers?

Interviewee A: [00:59:50] It does not as much as I used to. So when I sort of moved my for a firm wide role before all I say before I moved to my for my role I was always staffed on projects and working hand in hand with them. Now I've sort of moved to this role now. I don't do a lot of hands on project work but what I do is I do consulting with the projects I do train people on how to use these tools so they can run off and do it. And if they need to bring me and they can and then I can handle whatever they are they're asking of me. But for the most part I try and keep them much more higher view on everything and try and enable more people to do a lot of this stuff on their own and then I'm also trying to convince offices around the firm that they need to hire more people with my kind of background that are you know really passionate about creating this stuff because some designers they it's not their passion. And so not that they don't want to do it but it's just They'd much rather handed off to someone so they can continue working on the design versus worrying about renderings and animations. So and so I've seen them and I've seen an uptick on that like our Chicago office just hired a unity developer our New York office has hired some people. Our Costa Rica office has 14 rendering artists in the new motion graphics artist. So yeah there's definitely the needing growing of that kind of talent.

Interviewer: [01:01:25] How much do you have those people for example in LA. office compared to the design side?

Interviewee A: [01:01:33] Oddly enough there isn't any one like that in LA. It's a little catch 22 for L.A. and L.A. just is just for a little history used to be down in Santa Monica and they used to be next to all the major game and movie studios. And so when they would hire someone like me and they couldn't retain the talent because all of a sudden it was like: "Hey who wants to work on the new Tron movie." And then they lose every right. Now that they're downtown, I don't know if they would have that problem as much but even though I mean I know L.A. is big but it's not that big in terms of Hollywood so they typically they've stayed away from hiring artists like myself because if I have the ability to go work on the next Star Wars movie. Do I want to work on a building or do I want to work on Star Wars in terms that it didn't I think Star Wars is going to win that argument. So that's kind of why L.A. doesn't have a lot of rendering artists but they actually do have a lot of talented designers who like to render. That's that's always helpful.

Interviewer: [01:03:22] What kind of expectations do you have in virtual reality overall? Not just in terms of architecture or design, mostly overall.

Interviewee A: [01:03:54] I think I think in terms of design I think a lot of our expectations have been met. I think it's I think I'm what I'm. Like I'm keeping my eye on now is how the entertainment industry is handling it. Again like I said they are still experimenting they're still trying to find their footing. And I don't think they found it yet but when they do I think it's going to be pretty exciting only because I know how well we in design have used it and it's just been this earth shattering thing for us in the entertainment reason and the entertainment industry hasn't had that moment yet and. I don't know what it's going to be. I wish I did because I'd be really rich. But like I said I think it's going to be really interesting to see what they really do figure out and what that Aha-a moment is going to be for them. Only because like it's the experience that you get are just awesome. Yeah. That will be great. Yeah this is amazing. It has given so much it me. You already know. That's right. And very clear. Yes.

Appendix 2. TCA Architects, interview on the 20th of June 2017

INTERVIEW QUESTIONS:

LOS ANGELES

Name and (title): Interviewee B (VR Architect and Senior Associate) & Interviewee C (Project designer)

Firm: TCA Architects

Background:

1. Is it possible to record this interview?
2. When did you first try VR?
3. How did you start to work with VR?
4. VR can be a good sales tool for the architects, clients and construction companies, but I have framed my thesis to be about the design in the VR. Covering everything from the clients perspective to the sales to the end customer could make the research portion quite overwhelming. How much has the design process changed in TCA now that there is this new tool that you can use for the designers?
5. When the VR and AR was introduced the possibilities of VR and AR in TCA, how did the architects and designers take it?
6. Are you doing these kinds of design iterations still with the designers?
7. How much do you normally work with Designers and Architects nowadays?
8. How much work do the architects and designers do in VR currently in TCA?
9. How quickly do the designers start to use the VR in a project, from the beginning / contest phase? Later in the project?
10. Do they only evaluate the projects or do they use it as a design tool?
11. What kind of feedback have you heard from the designers?
12. Has VR/AR made their work easier?
13. What VR system do your designers use?
14. What does VR bring to the designer?
15. Can the designers use VR real-time changes for the design when they have the client review?
16. VR often raises players nausea, what other difficulties have come to the front?
17. Open blank space – does TCA have it now for VR Designing?
18. 3D sound – simulate sound (acoustics are worked into it)
19. Are the Architects and designers part of the Storyboarding of the VR journey?
20. Is TCA creating your own software for VR? App TCA VR already there
21. How do you see the future use of VR and AR in TCA?
22. Experience – clients perspective not just what you see – sound, interactivity, 360 degree fly-throughs, modulate speed, pause real-time. Do you currently have these options available for the client?
23. What game engine do you use (Unity / Own)?
24. Do you think that in the future the clients will expect a game-like content in the future?
25. What do you expect from virtual reality? What can it change?
26. How do you see VR and AR in the future? What purposes could it get? How does it change the world we are experiencing?

Interviewer [00:00:05]: What is your background?

Interviewee B: [00:00:11] I am classically trained as an Architect. I am 38. I graduated in 2002. I came up in the age where you were it was OK to draw. I did most of my thesis by hand. I'm licensed in California. I have a nonprofessional background in technology. I've just been surrounded by my whole life and I understand it. When this technology came out it was released years ago but when it started coming into the consumer market last year right around this time actually I wanted to see it because I knew that it was going to be really valuable. I just didn't know how. So first I just wanted to see VR before I started playing with some of those you know it was the Oculus Rift and it had like some cool VR experiences you know building and color down and other cool experiences or things are floating in front of you when you kind of look around them. I started realizing wow this is to be truly useful for what we do because you know the city that's floating in front of me is sort of cartoonish and fun and there is all this cool stuff happening.

Interviewee B: [00:01:29] And you're only meant to sort of lean in it look at it. But I would start to look at it like if this was one of my projects I'm looking at a smaller scale. I'm seeing all of the interactivity and the connectivity between all parts of the project. And I can literally walk around.

Interviewee B: [00:01:45] This is really cool. So how can we do this for architecture was the question that we were trying to solve. And so I inherently by playing these games I said oh this is amazing for what we do and now why is it. The answer to that is actually really simple.

Interviewee B: [00:02:46] Essentially what I said before is that our history is one of the few that works that works of scale. So with architecture scale is one of the most important things about what we do.

Interviewee B: [00:03:09] So if the scale of a design is wrong. The design is completely wrong. There's no ifs ands or buts about it. This can feel to hight, this can feel too low. So scale is really important to us. So it's not more it's more about scale and design. We have no way of accessing scale until the project is built because that's the only time to access has to be surrounded by the environment. So the only time we can actually get there is when it's built that we can get out there and say OK I like this or don't like this or this turned out OK or it didn't. But now it's too late. Right. It's not merely to say because we can change things but it's very expensive. And your client isn't very happy if you have to change things. So it's kind of those things and that allow us to say you know vr puts us in the building before it's built. So with VR I can walk into a project in a minute and the project doesn't exist yet. But you can have the same feeling standing in the room as if it didn't exist. We can even make it would work for a really think it is there. So you really think is there the value of that is that you can stand in a room and you can say I like this or I don't like this. And you can we can edit it and then we can solve the problem before it gets constructed. So it doesn't get constructed with any problems.

Interviewee B: [00:04:49] You end up to walking into a room that looks just like the way you saw the entire time in VR. So you don't get up into the final room and end up saying, this is not the way the room was going to look like. We need to get into space to understand what it is. So the real value of VR is getting into a project before it is constructed. As architects, our job is to is to convey very complex information in a very detailed and clear way so that somebody can build it. And usually this is done in two dimensional drawings really big thick sets of paper to 300 pages, you have to flip from the front to the back and they stand everything. The result is that you don't really ever understand anything because it's not ever served to you in a way that you see it normally.

Interviewee B: [00:06:07] So the way you see or what it is just like this just the way we're seeing this room right now you have perspective three dimensional view. So if I show you something in his view, you're going to start immediately because you're I always sees things like this.

Interviewee B: [00:06:28] For example I use the example of my mother. So my mother is not an architect. She's not trained in architecture background architecture. She just raised two architects me and my brother. If I my mom in this room right now. She could tell me how she feels in this that have no background in Architecture. They can stand in a space and say I don't like you or I like it. And this is why. Because it's too small it fills your credit fields whatever. And what they're doing there is there really anything that sounds very personal scale to the size of your space. So guy that's like two feet taller than me. We feel different in this room than I feel because his perspective is much different than mine. So it's all about personal perspective and how that employs a space and VR allows us to access that perspective in a world that doesn't exist right now. So since all the authoring technology in architecture is three dimensional, meaning we have we have Revit, Sketchup, 3D models that have mass and they have scale. It is not just CAD that lies on the ground, we can actually walk that 3-D model.

Interviewee B: [00:08:09] This is one of our project for this building. So this is a Revit model. So if I click on his wall all the data from that wall from Revit is available for me to edit. In this model that I've done, I've also brought in the interiors as a separate model so that this right here is pieces of a different model. This is a Revit model. And then with a window is another model. So what we did was we merged together a 3D world of LA so you could really get a view of what is going in here.

Interviewee B: [00:08:51] So if you're going to buy this unit and you want to understand what the views are from there would have to do is provide your virtual reality upon him before reality become the eyes of that user.

Interviewee B: [00:09:31] You to put this on. Now we're standing at scale in a space that currently doesn't exist.

Interviewee B: [00:09:42] On the controller there's a big circle if you push the top portion of that circle in your controller. And then when you let go you land wherever that guy is yeah that's how you teleport. So this was your living room. You can understand that this is your view from your living room. This isn't as high and you rendered as unreal or sort of like a video game. But the reason why is because everything in this model is still live. So unlike an unreal model where everything is completely static you can't move anything. And if you wanted to make a change. So if this was a unreal model that was of you know 10 times better. But if the client came in is it now "Can we move this wall?" We can't because this model was fully rendered and it would take another two days of rendering. That was what I can do in this program is I can click on the wall and I can move it. Now the model is here in VR is linked to the Revit model. So if I move a wall in this VR model it moves in the Revit model. I can have a client come into a space that he is not sure about it. And by the time he leaves that space is exactly how he wants it to be and all those changes were also made in a Revit model.

Interviewee B: [00:11:03] So now we don't have to have Interviewee C or me or some designer going back to their desk and spending another hour on top of the we just have doing work that we just talked about because we just talked about the work. We actually performed it while we were talking about it.

Interviewee B: [00:11:18] So the value of this real value of this is that we can have that experience and I think which way works will stay there for a second. And this is so this game this is familiar with games. So the creator of this system is, he developed Grand Theft Auto 3 and 4.

Interviewee B: [00:11:40] So this is this is literally Grand Theft auto for architecture. Now are in the lobby downstairs and you could teleport out those front doors and you can go down the street and you can go all its all live data.

Interviewee B: [00:11:59] And were three things that you wanted to look if you stretch your guy out and stretch your arm out you go through a hole down the bottom to go through and look up. That's our project. That model that you're looking at was not in any way especially created for VR. That is what our Revit model looks like. Most architecture firms either do design OR CDs very well, documentations. TCA is a rare case where we do both very well and we're very good at design. We are also very good at documentation. The reason this building looks so complete is because the project team put a lot of effort into making it look that way. So that's Fuzor.

Interviewer: [00:12:46] Do you export to Unreal or Unity, or do you use something like Enscape?

Interviewee B: [00:13:00] Enscape is a company that is a copy of this company so enslaved so going to be a cheaper version of Fuzor. It was copied from Fuzor. He started his company out of Germany so we could be sued. That's what really happened. So the truth is, enscape looks better for presentation stand point. But the new Fuzor 2017 changes the whole ball game. The reason why is because unlike anyone else in the game Fuzor has its own rendering engine. It doesn't run on Unity or Unreal.

Interviewee B: [00:13:42] And the engine that he is running it on is actually more powerful than both of those put together. But again this rendering is the most powerful engine for VR in the world right now and I know that as a fact. I've seen this thing over the model that Unreal and Unity crashed. This model is six million polygons. I've seen Fuzor open a model of 188 000 000 polygons. You could open it, but you couldn't use it because of the lag.

Interviewee B: [00:14:26] This actually optimized this model pretty well.

Interviewee B: [00:14:33] I advice Fuzor as well. I helped them develop these things. This is one of the things I helped them to develop. I

think that we could never do this before because it was too heavy. The model was too heavy but I cleaned the model a couple of weeks ago. And so we were going to scale mode.

Interviewee: [00:14:52] What was the reaction of all the designers and architects when you first introduced VR to them?

Interviewee B: [00:14:58] It was more like Wow.

Interviewee B: [00:15:00] I am going to take the controllers and scale the model. So now I am eye-level with the model of the model is staying next to me.

Interviewee B: [00:15:18] This is the cool part. So this stuff has all the data in it so you can stick your head in here. So if you're wondering what the views are, you can go right to the first-person view.

Interviewee B: [00:15:43] then if I want I could just quickly jump up and change scale.

Interviewee B: [00:15:47] The cool thing is this is something actually that TCA developed for a Fuzor. Fuzor did not have this functionality before I started advising them. So now I don't know the scale mode. If you combine scale mode and movement mode. You could just grab it and move it and then you can just go you undo everything and go back and go back and really look at this. It is a world that is. It is a Gran Theft Auto world. I mean so the other cool thing is that this project this program does, is that you can be in a wheelchair. And this wheelchair will not go up curves it will go up. So there is real physics involved in all this. So you can test the accessibility. So that is the way we get client immersed in the model, so we can solve real problems. The roof, wall or the floor is too this or too that whatever. I can also go away here and we can have a material pallet ready for you. We can change materials on the fly which is really cool. And then I also have another model. That runs smoother.

Interviewee: [00:19:17] How much do the designers and architects use the VR in their daily work?

Interviewee B: [00:19:21] So it depends on the project. It depends on so many things. But I'll say it doesn't get used as much here because I'd like. I need to put that on the studio directors to do. But I would say it gets used weekly in each of the offices. If it is not this setup, there is some sort of VR happening. But the thing is I don't mandate VR yet. I am trying to allow people to figure out on their own but it's going to come to the point where I am just going to talk to the bosses and say "Everyone's going to use the VR. You are not using it enough, so you are not getting the value.". So people like Gensler. They mandate it. There is 5000 people. It is the biggest office in the world. They say "you have to use VR". Because otherwise, how are you going to control 5000 people.

Interviewee B: [00:20:06] So here we're a lot smaller. So I have a little bit more luxuries. OK. So let's just kind of like see how it goes yeah, so everyone use it. Let's get some feedback, see how that goes. We're in no rush here. We have solidified our spot as one of the leaders in VR in architecture not only because we've been doing it longer than a lot of others but I travel to conferences this year throughout the world and I speak about this topic.

Interviewee B: [00:20:37] I'm invited to speak about this topic and the only other firm that I ever see there is Gensler which is the largest firm in the world.

Interviewee B: [00:20:56] I was at AWE speaking comes on Friday and a visualization director from Gensler spoke before me. There is more pressure on him which the funny part. No one knows about TCA like they know about Gensler. We are a smaller niche his firm but we are progressive because look at what we're doing in this small little niche like we are. The partners here they understand the value of what this is so they say OK we can do this but this. We have to do this now.

Interviewer: [00:22:17] Do the clients ask for VR?

Interviewee B: [00:22:20] So not, some do. The ones that are savvy do. The ones that are not, don't know how to ask for it yet.

Interviewee B: [00:22:32] The client perspective is totally different. The client perspective is, is this going to be very expensive. I am already paying you a lot of money. So why am I paying you more money to do VR. I don't understand how that works. So I said to the firm: thing we we're thinking that to sell this and we can make much money. So that thought went right out the window after the first couple months because I realized that it's more powerful actually and it's more beneficial to our clients if we don't. So if we just make it part of what we do. So what that says is, that you are going to come work with TCA and the value of working with these verses architects x y z is that we have VR and they don't plan. And so therefore we're going to be able to see things literally see things that they can't believe we can see and we'll be able to move faster in that process because I'll be able to explain things to you and show you. I'll be able to show you things for you to understand rather than trying to explain diagrams and emails and meetings all this stuff just to show it to you. And that's very powerful. Gensler told the story and they lost a job in Denver because they showed up only with their ego and not with VR and another from another little firm showed up with the VR and they beat out Gensler for the job because they had VR. Gensler has VR, they just didn't show case it to the client.

Interviewee B: [00:24:19] Like of course we can design this project and they didn't get it. It was a small project but still. You know it was probably over $150 000 opportunity for them and they lost it simply because of they didn't bring VR to the table. So we use it to increase the value position of the firm.

Interviewee B: [00:24:37] I say that because we are you know we just went out to bit on a project and we do that all the time. So if we're going to get bit a project and client is definitely going to other architects or other firms to do. We're doing a CD's on a project now so why what's the value of doing CDs with us that somebody else was about to do that. VR is one of the things but when you just tell and know that means I was just talking to one of the partners his office, said we need to put together a 20 seconds video that shows that we have great design that we have a great production, and VR is the glue that sort of holds those things together that allows us to continue to progress in that area. You can explain it to someone in 20 seconds you need it is hard. We need a video that shows the energy of our office working in VR to showcase like behind the scenes like these guys are really involved. A lot of firms use VR, like show you this panel, uu we did VR. They did not do VR. They just showed you a panel that any rendering software can create. So VR is really understanding and knowing the process how we can change things and the value and then implementing various work flows so that it benefits because the end of the day the VR should save a decent amount of money in terms of time and change orders and issues of construction and issues in design for the overall [00:26:20] liceptual [0.3] product.

Interviewee B: [00:26:22] If it is used properly but its the first part is getting everyone to buy into it. The second part is getting everyone to use it. As Interviewee C is saying, there is a lot of usage going on up here, where in I see more usage in Oakland because thats where our CEO is. And he was one of the main [00:26:40] ones. When I brought it to him, he was like go, go, go. He wants to use used all the time so I got to get the energy up around here and get it useful and more and then I talk to people around here. Some people think it's a waste of time. And sometimes it is for them. One of the CD designers: if he has designed this room in his career 30 times or 300 times, he doesn't need to go on VR in his room. He already knows what it's like. He knows what the dimensions are. VR is not needed. So for that we would be a waste of his time just keep going and pump it out because you know what you're doing. But for other projects we have which are a very complex they are just extremely useful. So I try to get. I don't want people feeling like I'm so busy or over that I don't want to take this extra time to waste my time because the value is going to save your time by furthering and speeding up your understanding.

Interviewer: [00:27:41] Are you included in the design reviews when they use VR?

Interviewee B: [00:27:46] I am. It's funny. No not always. Only if I'm around. If I am around and there is a client that needs to be shown VR, I am the default person to go to. If I am not around, they'll grab up one of my back go guys like Interviewee C. Interviewee C might not even be in the project but he is here just to make sure that the tech is alright and everything and then you'll have the people that are around the product will be here for the meeting. I try to stay involved in as many of the VR meetings as I can you know to help the client understand the value so they can sell it them.

Interviewee B: [00:28:27] This model is open but when you step inside this is what I call a marketing tool. This is an Unreal model, marketing level model. This is the highest quality model you can get these days in architecture. On the bottom trigger if you squeeze one of them just half way down into the ground there should be a little icon try the other one. To change the time of day.

Interviewee B: [00:29:18] And then now with the trigger that's in your hand, click at the wall.

Interviewee B: [00:29:43] You can change materials on a floor, on a couch and the walls can change the time of day. What you're trying to show a client a realistic view as real as possible as close to finished as possible.

Interviewee B: [00:30:52] So we would use this for marketing so instead of having a model unit, that you would walk around. Those model units have to be taken offline and they can't be sold. So what we can do is you can create VR model for the units then you could add the materials that you could have as finishes. The client can go through and select. Or the person that's going to use this place or rent it can select and get an idea of what it's going to be like and they all don't have to travel anywhere. This is good. This is virtual. So this could be served up to them wherever they're located or they can go to one central location where we have four or five models and you can jump from this unit and then you go into the amenity room and to the leasing office. You've done this whole walk that you can do in real time but you do it VR. So you're saving cost there for the client. You're saving a lot of time for yourself personally. So there's a lot of really good implications. And in this model, we can change color it looks really cool right. Really cool reflection. Nothing in this model can move. Nothing in this model can be can be touched around unless it's programmed that way. So when we built this model I can make I can tell my team to program those chairs so I can grab them and move those chairs but we don't know if the client is going to want to do that ahead of time.

Interviewee B: [00:32:14] So this is a static, in our world, this is a dead-end solution. It's good for marketing but only for marketing. So for us that's a very end of a project. In architecture everything is moving right up in to the last minute. The client is not making decisions on anything until the last minute. So I can't provide a model like that to him or her unless they're finished making decisions. We can make that any time, but if you change your mind and it's not programmed in to that model, we have to go back to the beginning to do it again. So you are not going to pay the same price because we don't have to modeling everything again but it's going to be expensive because of the rendering time. So it's not it's a fool whereas the other program user I can take my models I didn't say I thing.

Interviewee B: [00:33:09] But I can take any Revit models, Sketchup models, Rhino models or any other 3-dimensional model and I can drop it into Fuzor. Fuzor will build it for me and allow me to walk around it and do everything I want and if I make a change I can reload and it links back and forth. So that is something that we use for all the changing, all the back and forth, all the issues all day. As were in our design process and our CD processes things are still moving and it's a good check to make sure that things that we're doing are resulting in the way we want it to. You can have a vision for something in your eye in your mind. And then when you get there it just to come out that way. It just manifest that way, something happened, where between your sketch and the final drawing that there was a misunderstanding. It just didn't come out the way you wanted it. You have to figure out. So VR is an easy way of cutting through all that I'm saying this is what it's going to look like. If you like it cool. If not, then let's change it now and let's get to a point where you like it. This is not you looking at drawings, you're standing there and you sort of feel the height and how these things are sort of understand that as you say go on this or then it's a go because when it's built, you're going to have the same experience. It's just that when it's building the environment it's going to be real. And now it's virtual. And it's really better to catch all these problems in a virtual environment. Because it doesn't cost a lot of money to fix.

Interviewee B: [00:34:47] That's what we use it here. So it's going to increase in value position and it allows us to access new data and the new data is get get to scale. We get to a room of scale. So it's it's like going to drive your car before you buy it. You're going to go drive it.

Interviewee B: [00:35:08] You're going to go sit in it you're going to go see if you like the way it feels and try this and that. And what you're doing there is sort of testing to see whether you can live with something that you're going to have for a long time. Probably right. So. VR provides the same thing for a developer. Developer is going to spend a hundred million dollars building a building.

Interviewee B: [00:35:33] So if that's his money he will probably want some sort of insurance against the money he's going to spend that he's going to get what he wants because he's going to live with that building for a long time. Those buildings go up and they don't get knocked out in 10-20-30-40 years. Now if it's not his money that means he has a hedge fund by then and the whole idea behind hedge funds. That they hedge money and hoping to get returns. So when someone hedges money it's always better if you can give him a bit of a surety or a guarantee against hedge. So it's always better that I guarantee you you're going to make money or might you hedge your money here, I have this spreadsheet that shows you all the data of this and it shows that most likely in the next six months you're going to be a lot of money versus invest here. That's the difference. Work with us and we will show you the finished product before it's completed. Or you can walk around it and you can you know feel it before it's built and we can solve any problems before we have to deal with them in the field and the problems can just get very costly. You know the products in constructable. The team that have designed it in, and after the CD's they're no longer working on it. They are on another projects. So something comes up from the field on the product that's a been on the construction for three months. Interviewee C's now six months into another project.

Interviewee B: [00:37:16] Now he's got he's got to stop what he is doing. He's got to find his old files that he hasn't seen you in three months. He doesn't dig through them and solve the problem. He has to get an RFI out to somebody or he has to respond to something he has to call somebody he hasn't talked to in three months and they have to figure out this problem. This takes a while. He's bill his time somewhere but that's just for one RFI.

Interviewee B: [00:37:42] You get hundreds RFI's from a project in construction that people don't know how to build and you can spent months and then the construction cost goes through the roof. So it's a matter of like getting the word out to everyone like if you're not using this, you are behind. And so that's kind of like many years later that we're 10 years 11 or 12 years into the adoption of Revit. So Revit was really adopted in 2005 or 2006. It was invented in 1999-2000, purchased in 2000-2001 and put out to the market but no one cared about it until 2006. It was like I don't need that, I am using CAD. And the second you change, you are like holy crap.

Interviewee B: [00:38:26] This is so much better. I just did three weeks of work in one week.

Interviewee B: [00:38:39] Now is to the point like if you don't use Revit, nobody really wants to work with you. That's what's going to happen with VR. It is just going to happen faster. So we are this cool firm right now, in 5-10, if you don't have VR, you are not going to get any work. By that time, we are on to other things, AR, MR or what ever the next cool thing is. I'll make sure this firm is the first flown into the next shot. I already am making sure of that.

Interviewer: [00:39:13] What are your thoughts about Mixed reality?

Interviewee B: [00:39:13] You know the thing with AR is it is really cool. It's not as applicable in our industry as it is in another industries. The reason why is our industry is because our industry, AR requires some sort of a level of reality to augment or in my world the reality we are there's no reality to augment. Everything is brand new. So it has to be VR. But AR has some really cool applications for example in our world where we going to use AR in the future. I haven't even begun to implementing here because we don't have any goggles because I'm not happy with them. You shouldn't have any yet. And they are very expensive. I can download AR goggles on my Siega in the field and I download the Revit model into his headset and he walks around the field and he has AR vision for overlaid on top of the way the building is getting built.

Interviewee B: [00:40:13] He can walk around and be like, that's not right. As you see his model overlaid on reality. I've seen a person done this already once, where they built of a small room using only the Hololense, nothing else. They programmed the whole thing in the Hololense and the guy stood out there and was able to look. And based on what he saw they placed the studs based his AR vision. His AR was showing all the studs, they weren't yet there and he was standing there, "Put the stud here." And he could see on the screen how to line it up. That's what's going to happen. You're going to be able to see or like AR into the wall. But it's not x-ray it's only because I have a model of this that has all this stuff. All I did was that I aligned my location here to my location in the model. Once I go inside to my location in VR with my location in actual reality, then is easy. Then you can overlay anything with AR.

Interviewee B: [00:41:17] But VR is going to have a stronger hold in our industry longer and AR will be for construction sidewalks and things like that. Or if you wanted look at a project that's flouting in a middle of the room here so you know where you and I are going to discuss about a project. Well then Interviewee C and you and I would all have our AR goggles on and we'd all be seeing the same thing floating here, but from our unique perspectives. So I would see this going on so I'd see from the side Interviewee C would see it from that side you see from that side. But it is digital. What if we took this mass and we put this mass in and kind of looking to see it CNN. Interviewee C couldn't even move this over. That is how AR will help us, because the problem VR is right now is you have VR isolation. So when you're in there you're in there by yourself. And I can see what you're seeing where he was. But there's nowhere and there's no one in there with you at the same time in the same space. So yesterday we tested collaborative VR. So Fuzor we can do clever VR. I can be in OC and Interviewee C is in LA and tell him to jump into VR room and give him this code, type this code in the Fuzor and hit enter. Then him and I can both be in the same model. So we both have our own avatars, and it's free roaming so Interviewee C can go this way and I can go this way, we can do what ever we want. But then I hit a button that says tour mode and Interviewee C will come immediately to me and he will be attached to where I am going. So we all go together.

Interviewer: [00:43:14] So you can guide the experience?

Interviewee B: [00:43:14] So I can guide it or everyone can come right to me. So that is powerful because we could be anywhere in the world it is easier now. Our offices are on a VPN all three offices run a VPN virtual private network. So as long as he's plugged in to the VPN as long as I'm wired I can seamlessly connect any computer in your office.

Interviewee B: [00:43:45] So I can connect to here like we have Oakland, L.A. my computer and this one all jump in this same model. Gensler has weekly VR jams and they have 50 people in the models sometimes 60. Which means they have to have 60 Vives, 60 computers, 60 copies of Fuzor. But that's Gensler, they are on that level. We have three Vives and we're going to get another copies of the Fuzor so we can. We're in we're going to be doing them on the regular basis. The president of our firm Ram, he is leaving next week in a vacation. He tasked me to have this set up this week because he wants to begin doing that more. He doesn't know it yet, but I haven't finished it yesterday. And I have to tell him that we are ready to go. It's easy to do.

Interviewee B: [00:44:34] The issue that I am having is getting everyone to use it. And it's the same issue that everyone having. Gensler has the same issue.

Interviewer: [00:44:45] Do people have motion sickness, is that a problem?

Interviewee B: [00:44:46] I don't, people do. You've got to be careful. You got the motion sickness comes from latency. So you need something. And the thing about VR that people always misunderstand. The second model I showed to you was really cool right. Really highly graphic. That is secondary in VR. How cool things look, it is secondary to the experience of the Fuzor. So I would rather put you in a VR model that doesn't look as good but is really smooth. Every time that a model that is really cool it is like every little bit stutterers because that's not a good experience. And the only thing they are going to remember is the stutter. So with VR is not just about the pretty pictures it's about having a really smooth experience because they have this smooth experience. You're going to see how these people get right to work. They're going to start like, "oh this is really cool". Let's move this, let's do this. It something that I come up with is called Wow-to work flow effect. The real users put the goggles on and they get right over the wow and go right to work.

Interviewee B: [00:45:55] See everything. Oh I didn't know this but this was like let's move this wall, do this. And I have users put that on and just be wow-ed.

Interviewee B: [00:46:09] Then they sort of need me to sort of hold their hand like well this is what we can do with this. It's not just cool. We can make a really cool impact on an investor.

Interviewee B: [00:46:18] But this is going to save you money and time. This is this is not just like a gimmick. This is not just like this is this is the future of our industry. And if you don't think that this is going to cause a disruption in architecture it's going to cause a major disruption architecture that people don't even know about yet for. People don't know about. And people are not accepting it yet. I talk about it but people keep shrugging their shoulders. You watch the next year there's going to be a huge disruption in our field because of this technology. Things are going to change drastically and people again you're going to have to let go of the old because it's better tech and if the people that spend the money say that they want this tech. Guess what you're going to have this tech. The guys that pay for the projects. Not to guy that pays your salary. The guy that's building your next project, who's spending another 150 million on you. If he says I want VR, you bet you're going to have Vr. And if that hedge fund controls 20 percent of the projects in Europe, or 15 other projects in the United States. Then what do you think is going to happen. You're going to have 50 percent of your project in VR every other one is going to follow soon. All you need is one or two or three major players to say this is the way it has to be. And if those guys are big enough dogs. And if the big dogs start barking nobody gets that right.

Interviewee B: [00:47:46] So if these guys are big enough and they're saying VR then guess what everyone's going to transition. It's going to cause a huge disruption to the industry and people are not going to get work because they don't know the tech. There is going to be scramble to understand the tech. And there's going to be a lot of craziness as a couple of years ago in our industry when people were scrambling to get to Revit. A lot of firms made mistakes and a lot of firms lost jobs. A lot of firms did really well. Our firm did really well and a lot of firms didn't do really well. They hired the wrong people and spent a lot of money hiring and firing people. They didn't know what to do. So for me I'm trying to get TCA in the position or a place that when we were taking the next step by the time the other firms are figuring out what the next step is. We've already gone there. So we've got for example if you've done this have you done it like I've done everything and stuff you stuff that you thought about yet. When you think about it next week, I've thought that too.

Interviewee B: [00:48:38] And you can email me and I have thought about that too. Because I just have. I've done this demo at HTC headquarters. I've done this demo at Facebook for Oculus. I've been in the door at all the major players. I have connections at Veet motion and I have a connection at the Magic Leap. I can call Magic Leap and they pick up the phone . That is the most secretive company in the country. I can get a person on the phone because the tech guys. You know we are all tech guys who has a background in tech especially in

this era because it is still new. It needs to become worth of a lot of money before everyone starts stabbing each other in the back.

Interviewer: [00:49:12] So what about storytelling or the client experience once you get them in VR. How have you approached that matter?

Interviewee B: [00:49:31] Storytelling in our field can go from as broad as here is the concept. One another thing I love about this firm is that every project has an idea of a big idea what like in school you're taught the concepts drives a project. In the real architectural world that never happens. It just doesn't exist. Money drives the project. Profits drives the project. Not at TCA. I mean just literally every project has a big idea and the project serves that the idea no matter what. So the big idea is the concept. And the concept is not something it's usually kind of esoteric concept. So it's not like a case where next to you know a little park and we're going to open up and respond the park is going to say was like an old Indian burial ground and we're going to have you know we're going at it.

Interviewee B: [00:50:24] The way it is aligned with the stars, the buildings are going to reach out you stars where the people died or something. It is very conceptual.

Interviewee B: [00:50:32] And that's how we operate here which is one of the reasons I really like this place is that there has to be a big idea. So the big idea of the storytelling can relate either to the big idea or we can relate to the story, I think they really want to hear is what we call is the "Leasing walk". Everyone cares about the leasing walk which is how we get from my car to the leasing office from a leasing office to the first amenity of space. And from the amenity space to the pool. Because when you bring someone to your product. That's how they go take the tour. We can Storytell from a variety of ways. I have lots of tools at my disposal not just what I've shown you with Google Earth VR. Google Earth VR or you could be standing at scale anywhere in the world. So I was like I can make you the size of your building.

Interviewee B: [00:51:23] If you're in one of your high rise in New York City. I can put you in New York City on your site you can stand on your site you can see a tall building is going to be to get some of your views are or you know or you can be down the street looking up. You can be any scale. So it really for me I try to understand from the client's perspective why is this client coming in. What's the point of the project. Why are they using VR and if they want VR, why. And you then you tell me what your end goal is and I'll tell you what we need to get there. Without lying to you or upselling you. I am going to tell you that this is what you need and I'm not going to lie to you. I am going to keep it very short, I have no time to bs anyone, I am very busy. So we we're going to work with this or not and if not we're going to the next opportunity. But most ones listen because they have a real goal and the real goal that they're trying to achieve can really be helpful in VR. So they really listen and they're open and they don't want to pay too much. Right. But they want to pay. But they have to pay something they know. So you have to be able to hit them with at a price point where it's acceptable to them.

Interviewee B: [00:52:24] You know here's this is some pocket VR. Couple of weeks ago we had Burbank town center that on one of our projects, I did these in Lumion these renderings. And then this is the next hotspot you can press that and you go to another hotspot here. And then you can go down here. And then I can do this using my finger. I use it just using the phone or I can go into actual vr mode. And then if I stare at those hotspots for that it'll load me right up to that.

Interviewee B: [00:53:01] So this is like in your pocket VR or in the future VR is what I'm showing you right here. Well the future VR is this is not that. Something that's easy to use. This is the future of this is for getting work done in the office.

Interviewee B: [00:53:18] This this is for work. This is not the flashy cool apple laptop that I show my cool people. Yeah. Or my ipad. This is like for the office work. This is on the go. This is going to go away too, in the next year (points at the headset cord).

Interviewee B: [00:53:37] And that'll help a lot too. But that Cord is there for a while because it disappears and it goes late. Everyone's in trouble because everyone won't have as good of an experience.

Interviewer: [00:53:50] Do you think about the sound in the VR system?

Interviewee B: [00:54:01] That's a good question actually sound. So I build models that.

Interviewee B: [00:54:05] In those few models for you and I can embed sound in those models, I can ebbeds ound in objects and it's point source sounds so further walk from it, the sound dissopates. So in the Fuzor models, and in one of them I have like on the street I put some street noises and trees and birds as you walk around you sort of get that feeling. [00:54:29] But I got to really do it. Way like it's enough trouble get this thing go on (pointing the headset). The last thing we can do is put some earbuds in top of that. So I kill the sound right away. I think it's cool. I like that. But you get don't go around the office and people think it's good that you're not going to on. I don't think they will. So there's a way to do it I think of these computers we have you don't think they have sound cards in them or the other one doesn't. They're just true graphics machines. Plus you didn't have the sound play room because you still get the birds and you're still sort of virtual. But it's now a trouble getting someone to put this on. Because especially females. [00:55:09] Because females and their hair and makeup and guys we don't care it. If you mess up our hair, we just do this and we are done. Executives have got seven high power meetings today and I am the first one. He is not going to mess up his hair on the first meeting or his all look just to jump in the VR. Right. So you can't hold the Vive like this (holds it on his face) just because my hand is covering whole bunch of sensors. It doesn't work. So they are trying to find other solutions to keep things more open.

Interviewer: [00:55:46] Do you have moving people in the models?

Interviewee B: [00:55:56] I do. So this one is going to load up as people sitting and walking. So I put people in the model for scale. In the beginning I didn't just because people could get scared. I put cars there too but sometimes people get hit by the cars, but it is kind of funny, it makes it more fun.

Interviewee B: [00:57:04] This is the Fuzor so this is called VX GI render.

Interviewer: [00:57:11] And those models are from Fuzor?

Interviewee B: [00:57:11] Yes. What I'm trying go to the rendering effect. The biggest change in Fuzor was this render VX GI. It has changed everything and it is called Vauxalt Global Nation rendering. This is the beta version of Fuzor that I got from the conference on Friday. So it's got the new interface is updated and it has some cool stuff to do.

Interviewer: [00:58:18] So would this program is something that you want the architects to use?

Interviewee B: [00:58:25] They are using it. It is all in the computers.

Interviewee C: [00:58:51] When you are designing a building and want to show the scale, you show the environment surrounding the building.

Interviewee B: [00:58:59] You can change all the lighting, all the ambience. Getting all these lighting effects here. So it does now it takes like reflected light and it bounces it around. So is before. And it's a huge difference. You can turn the avatar off. You can walk and you have light following you. On a darker hallways is, there is no light in here, this is just reflecting light. So watch once I enter the hallway now, and watch when I enter to the light. Reacalibrates everything as you enter. People stay walking but my cars didn't. And over the years people screwed

up and but the materials look a better. The most impressive part of this model is this, the context. In VR you need some context. So we brought in the real context of LA. You really get a shot of what your views are from your windows. Because that project is all about views.

Interviewer: [01:01:20] What technology are you currently using? You mentioned Revit, Sketchup, Fuzor.

Interviewee B: [01:01:20] No, not really. I trying to keep things as simple as possible. The reason we use Fuzor is because it can be 10 times or maybe 20 times what Enscape does. It also cost a lot more.

Interviewee B: [01:01:44] Whereas Enscape is maybe a $500 a year and Fuzor is $4000 or $10000 a year depending which one you are using. But it's a bargain in terms of what it does. Fuzor, and standard architecture Software and Lumion is our renderings software but it is kind of standard these days. Sketchup, Revit. I want to keep the process simple. These guys are not tech people or developers.

Interviewee B: [01:02:16] They are architects. And one thing I understand is architects. So how do you get them to work with us without without making it scary. Right so you try to give them whole bunch of new things to do, then no ones is going to do it. Got to keep it simple, one button, one push kind of stuff.

Interviewer: [01:02:37] What do you think that VR is in the future for Architects?

Interviewee B: [01:02:38] I put VR as a standard for what architects do. It is going to be. 10 years ago no one knew what Sketchup. So when I graduated college Sketchup just came out 2002, maybe just a bit after. Every firm in the firm has multiple Sketchup licenses right now. Why? Because there is a value of a very simple modeling software versus 3ds Max, which is the old one which is ridiculously hard. And you can't scale that you can Sketchup. So VR is it's like asking do you think the pencil is going to be important in the future of architecture. Yes it is. And I think the VR equipment is you can it as revolutionary as using a pencil for the first time because you know it just makes things easier but it's not just ease it's new information and that new information is vital to having project success which is why I think that it's going to be required by any firms that are smart. It's going to be required. Not use every day or on every project but they have VR involved in your message in your and what you do in order to attract clientele. I think so. And the next chapter gets how to get it lighter and get it in your phone. [01:04:25] VR is going to demand models get smaller and lighter and clients are going to want the models to get bigger and more detail. So how do you resolve that issue. That's another issue has to get resolved. Tech companies will come up with that pressure and they will figure that out.

Interviewer: [01:04:51] So is this VR setup always here for the designers to come and use it?

Interviewee B: [01:04:51] Yes this is permanent. We actually have to get these mounted up on the ceiling. I just haven't done that yet. And this will be even more permanent. This is a permanent set up. So the architects, designers who really want to use VR in this office's will come in this room. This is the VR room.

Interviewer: [01:05:10] How often do you come here?

Interviewee B: [01:05:10] Once a week. Depends on the project. Sometimes it requires more. What was the title of your paper?

Interviewer: [01:05:51] Designing in Vr, Designing with VR.

Interviewee B: [01:05:52] One thing to look at is, I mean, that we're still very long way from actually designing in VR. This program does not even exist yet for example VR Sketchup would not be succesful. The reason why is because I don't want to design in VR. I want to experience in VR but I don't want to design in VR. Because you have to move my arms and have to walk over here. In Sketchup I can do everything with my hand and I have precision. And in VR there is not that much precision with moving your arm. So designing in VR is a long shot. I don't know. I'm not sure I'm not sure that ever happened because. No matter how much technology has come up with respect to design change or design it never beats my sketch. My sketch is faster than any program you have. The sketch has never left architecture. The napkin sketch, the quick sketch are always there. That little sketch sometimes drives a huge team of people to do crazy things off of one tiny sketch. Usually Starkitects operate this way. The story of Frank Gehry holding the paper and throwing it to the ground, and there is the building. Go design it. Interviewee C and I work like that so that we get a tiny little sketch in you have to figure out the building and fill in all the blanks.

Interviewee B: [01:07:24] So I don't think there's going to be a replacement for sketching and quick simple modeling software because if you tell me that you can go build this model VR, you're going to build this house and all this stuff with my hands and then jump in the VR and you look at it. I could do that in sketchup twice as fast or download assets or have assets already have made a ready bring them and put it in jump in the VR. So I think we're a really long way from designing in VR and I am not going to say that it is never going to happen. But I don't see if you go all the way back to how it works. It requires you to be doing a lot of things. And I think it's faster so that you just do it because this is business. We have to be efficient. So I don't think. I've advice for a company in India. They were trying to create a program we drew in VR and I told them: Don't waste too much time on it. The kid who developed it is a genius. He's not an architect but he's a genius. This is never going to work, no one is going to use it. And that's why I advise them, they expect to hear that stuff from me. No, keep working on this one. No you guys are way off yeah because they have been doing this and that to me is you can say OK we like it three times and do a lot more stuff with the sketchup because now you know we like draw each window and that doesn't. And the things that we want to create. You know even our super models these days are not so simple.

Interviewee B: [01:09:01] You know we you know we have the glass stuff and there's still the way certain things are that simple massing still show glass, show that I think that would be a pain in VR. you find yourself like walking around to do work that you would just have to move your thumb for. That's why I think that it is not going to work. But as a as a supplement to architecture from this point forward. Forever and always it will never go away will never go away unless we find a better way to do this. But I don't think there is one other that you know we're leaving ourselves to some of the cables and maybe you know a lighter cleaner a simpler tech. but that's just the tech evolving. from a grand standpoint I think VR is what it is it's definitely here to stay. It's not going anywhere. In fact I'm going better jump on board now. It's just the way to do it, so it is really cool that you are doing your paper on this.

Interviewee B: [01:10:04] So I came up with my own title last year at the time at the time or like four or five of us in United States who has this position. A year later, I think there is at least 10 of us. Not really growing that fast.

Interviewer: [01:10:26] It seems that in Finland, only a few architecture companies have realized the value in this.

Interviewee B: [01:10:26] Same here. And I was just I was you know it was over in London recently and at the same there. Some people are jumping on it, but the ones that are jumping on it, are really going for it. They're making a huge play when they're using it to differentiate themselves. That's what TCA did, TCA did a big play way into VR by investing money and time. You're pulling me off of billable project to do this stuff. You know it's like they loose money like that right. They see the value of doing it. So you got the Vives. It is rare to have this firm that is as small as TCA to jump on something like that but it just goes to show how progressive this firm is. And that's why we're still around and successful. You got to change all of it to keep up so you can keep doing the same thing every day. You're not going to keep up or get anything new. It's a reason to talk to all of your clients all over again. That's at a minimum. That's a reason have every client to come back and get some projects. Hopefully.

Appendix 3. 3rd Eye Studios Interview on the 23rd of May 2017

Interview questions

Name and (title): Interviewee D (CEO and founder) & Interviewee E (Lead Artist and founder)

Company: 3rd Eye Studios, http://www.3rdeyestudios.fi/Background: Video game companies

Which game engine are you using?

What headsets are you using?

Do you use VR headsets constantly during the designing process?

Why did you start to develop VR games?

What VR tools are you using?

What does VR bring to the designer?

How have you tackled with motion sickness?

What expectations do you have for VR?

What can VR change in the future?

How do you design the game, first on the 2d screen and then in VR?

What sources of information have you used?

Interview started with testing and playing the VR game co-opp with Interviewee D

Backgrounds: Interviewee D – Digital Chocolate, Redlynx, Fathammer, Tilt Tv (producer). Interviewee E – Red Lynx, Bugbear, Nokia UI & UX, artist

Unity, they have created and developed their own tools that can be sold to other studios.

Oculus Rift and Vive, high end headsets, with hand trackers. Better graphical features, and technical strengths

Large tv-screens as computer screens, they check the graphics through headsets, more detailed and specific rendering than normal game, assets and collisions are different, audio means more, audio brings immersion, good for architecture

Big interest from Valve rocket lab. It was the first one, that showed promise and proof that VR games work. Vive brought more opportunities, use is still limited, wanted to be one to create rules for VR games.

Motion sickness, often for users, limited walking, not a lot of people using VR, space limits, prototyping set up

VR and AR mixed, change in how we work, communicate, learn, fly, study and development of the technology

Teatime research, FIN VR

First designing on the screen, no designing in the VR, testing mostly

Appendix 4. Teatime Research on the 30th of May 2017

Interview questions:

Name and title: Interviewee F (CEO) and Interviewee G (COO and the Architect)

Company: Teatime Research

Which game engine are you using?

What headsets are you using?

Do you use VR headsets constantly during the designing process?

Why did you start to develop VR games?

What VR tools are you using?

What does VR bring to the designer?

How have you tackled with motion sickness?

What expectations do you have for VR?

What can VR change in the future?

How do you design the game, first on the 2d screen and then in VR?

What sources of information have you used?

Game project, pollen, VR demo 2015, team, architecture, coding, 3d artist

Svr, UX design, user driven, emphasis, motion sickness, uncomfortability, embarrassment, testing, data

All ages, educating the user on how to use the VR

3d model for Unity

Interactivity, use in sales, AR VR, high-end

Expectations, education, content still expensive, sales & marketing, demonstration, idea, spatial, functions of the space, industry, medicine, entertainment, social aspect, mixed reality, programs and software

F35 pilot plane, literature, Tilt bruch, Vive alt space, interior design, fabrics, theme of the interior, customization

Building, textures, model, textures, accuracy, Honka rakenne

Leasing of VR gear, VR demo area, fair, service, package, 3 years

Appendix 5. Visit to Gensler on the 9th of August 2017, notes

Visiting Gensler and attending their VR Jam, VR with Fuzor and intercom. The license to change things together costs more, maybe will purchase in the future. Weekly event, usually presenting their own design, and everyone can see it in full scale. Oculus Rift headset was used. Gensler was the first architecture companies to use Fuzor. Now a lot of the architects don't like the rendering style, and have moved to Enscape.

The meeting was managed an architect that has become an expert in using VR in Gensler Los Angeles and has been leading the VR development in the company. After the meeting, we toured the headquarters of Gensler and she described their work habits and how their whole company is divided into studios. After the tour, we went to a design discussion about "VR vs. scale models". It was very beneficial for my thesis. Fuzor for construction companies, that design the phases of the development. Technicolor, Upload VR, demos, software, Hololense

600 people work in the office, 4600 in the whole Gensler. The interest for the technology started among the employees and Gensler gave them resources, when they justified the need. Growth and opportunities in the market.

Conversation, scale models versus VR. 20-25 designers & architects talking about the benefits and challenges of VR. The conversation was opened by an architect who started her career with building scale models. Nowadays the scale model building has already changed because of 3d printers, laser cutters. Need to have scale models won't be going away, changing because of VR and AR. Benefits. Gensler should put resources in this technology. Not only other studios, but other developers can do visualizations, have to stay current and develop skills, lot of virtual content that requires designing, work and revenue

Debating about the use of VR and how it has and will change their way of working. Lot of opinions about the use of VR, cannot control the clients experience well, can see a lot, 360 degrees, can detect mistakes, efficiency in the design, hardware clumsy and awkward, no understanding yet what possibilities it can bring. Architecture is changing, not just a unique work, that nobody understands, open for others, counter reaction - always good architects and bad ones not related to tools. On the other hand, a lot of time in the traditional way of designing without VR, could show sections and there is still time to figure the design, understanding of the client is now better, have to be quicker, one step ahead, client expectations have altered. Communication is easier, no one has to explain how to experience the space.

Anxiety of how work will change, employment, other developers could step in the job market. VR has brought realistic sun studies. Massing is still easier in scale models. Sometimes using material from old projects to help to describe the goal but can communicate a wrong image. Can see instantly what works and what doesn't. Can we show as much as VR needs. Scale model sometimes communicates more. Time limits.

How to make the model look finished but not too closed. If the tools develop further, that the software is not awkward, the tool will be much more used. The role of the designer changing. Designing projects deadlines, phases, deliverables - what does VR bring to these. Guidance of the client so that they know what to expect. Using the tool, teaching the whole staff, that it is understood how it helps. New work environment, rules, habits, expectations and guidance of the client.

Appendix 6. Meeting with Disney Imagineering & VRLA on the 9th of August 2017, notes

Interviewee H: visual effects artist for movies like The Amazing Spider-Man, Divergent and Maleficent, , fun park experience designer

Interviewee I: a CEO of VR Los Angeles, about the benefits and challenges of using VR in the movies. Interviewee I has developed virtual production pipelines for many of the leading companies' like id Software and Epic Games as well as for movies 'Benjamin Button' and 'Ready Player One'

Interviewee I is working as the CEO of VRLA (Los Angeles VR convention) and Interviewee H is creating the experiences for the clients who visit and using VR and AR as a tool to help with the design. Both of their perspectives shifted more towards to get entertainment value of VR but there were a lot of similarities in their opinions about the design process in VR. It is easier to communicate about the project with other people and presenting the virtual project gives a deeper understanding of what needs more work and improvement in the project. It is easier to discuss with managers and directors; which parts of the design are not finished. Funding can be easier to negotiate for the project with VR. Interviewee H's detailed descriptions about the design process could not be recorded in the thesis.

Appendix 7. Design process research results

Construction and building planning

Partanen (2003) has explained the two building planning steps. The first goal in the planning phase is to assess the usability criteria and criteria of experiences. The usability criterion are; the time flexibility, the healthiness, safety, durability, versatility, important functionality and functional versatility. The criteria of experiences mean the users experiences about the space, how the space orientates the user to functions, what stimulus does the space offer, how does the space relate in the environment and the users experience about the aesthetics of the space. The second goal is to create the required drawings. The drawings are sketches, technical principal drawings, methods of construction, construction explanation and possibly even contract offer requests and offers. The owner and user control that the goals of the projects are met (Partanen 2003).

Lahdenperä and Tanhuanpää (1996) have divided building into six different stages; the requirement clarification, project planning, sketching design, implementation planning, building preparations and acquisition of building materials and construction. The requirement clarification is required to determine the scale and extend of the project. The clarification processes the necessity, qualifications and projects' realization possibilities. The gathered information will be needed during the planning project. The planning phase is economically crucial because over 90 % of the building costs and most of the living costs are finalized on the drawing table. Good design will make the house look good, be durable and meet the user's needs. It is good to reserve enough time, use professional knowledge and have enough financial resources for the planning. In this phase, the needs of the user should be clarified (Lahdenperä & Tanhuanpää 1996). The project planning phase starts with clarifying the clients experience in construction, resources and economic situation. The second step is to clarify the project needs and background. The third phase is to define the goals of the project. This phase acknowledges if the project requires special knowledge. The fourth phase is defining the measures and risks in the project. Fifth phase plans the costs and funding for the project. The sixth phase defines the users, timetable and collaborative partners. The seventh phase selects ways to evaluate the project and how do you continue the project onwards. The last phase is communication of the results (Lahdenperä & Tanhuanpää 1996).

After going through the requirement clarification and project planning, the building planning begins with sketching design phase and implementation planning. This phase starts the sketching and principle drawings of the project that include site layout, floor plans, sections and elevations made with AutoCAD or Revit. The sketching design phase defines the technical systems and building method. The implementation planning phase defines the drawings, prepare the purchase and make the construction agreement. After these phases, the constructing the project starts with the preparation and acquisition of building materials and construction. (Lahdenperä & Tanhuanpää 1996).

Building with steel

A steel can be considered as a sustainable development material if the material is exploited properly. Steel-frame structured modules provide energy-efficient building solutions. The steel has a low heat storage capability that can eat its energy-saving capability. The processing consumes a lot of energy (Väisänen 2007). MinunLOFT houses are built with a steel structure from recycled S355 Steel (MinunLOFT 2017). Structural steel must not be in contact with moisture as it may start to rust. Rust reduces the durability of the hull and can cause structural collapse. Steel treatment can be used to protect the risk of corrosion. Steel is naturally non-combustible material, but in the event of a fire, its durability and strength are greatly reduced. Steel can be protected with fireproof material. The steel structure is isolated from the fire by covering the structure with plates, spray materials or flame retardants, where construction costs grow slightly but the structure is then more durable. Steel reduces the possible growth of mold as the home begins to form when moisture gets into the structures (Väisänen 2007)

Advantages of steel	Challenges of steel
strength-to-weight ratio	expensive
good-small structural dimensions	loose structures permitted by steel
lightweight	strength can lead to stability problems
construction joints and fastenings easy	bends at high temperatures
possible to make larger changes easily	perishes in cold but can be solved with the right impact strength
homogeneous material	surface corrosion problems
can be produced with the desired properties	work on the site is to be avoided - no changes in the design
humidity variability is irrelevant	
nonflammable material	
good abrasion resistance	
corrosion is generally relatively slow	

Fig. 36. Advantages & Challenges of steel

The steel structure is the most widely used material in commercial and industrial construction. It can be customized to almost any shape, weld or bolt together. Steel construction saves time and reduces timetable problems compared to concrete. The use of steel is more useful in the construction of high-rise skyscrapers than concrete, since a small amount of steel can be used to ensure the strength and durability of the building. This means that the construction of low buildings will lose the steel's advantage over other materials, whereby concrete can be a more advantageous option compared to steel. Simple structures such as rectangular single-story houses or garages may belong to this category. Steel and concrete are not necessarily the best building choices for the house. Different companies and designers are accurately calculating the yield of buildings compared to their construction costs. The price of raw material (steel, cement, stone material, wood) is constantly changing. The price of raw material and the place of construction have a great influence on the choice of material in the structure. The price of energy and material transport have a great influence on the progress of the project. All these choices should be considered before the design process starts (Väisänen 2007)

Ecological aspect

The biggest challenge today for construction industry is to building sustainable. European union has decided to reduce emissions to a sustainable level by the year 2050. Building and use of buildings consume 40 % of the energy and natural resources that humans are using and cause 40% of all the waste and carbon dioxide. It is smart to switch over to sustainable way of constructing before exigency. The near zero energy house points to the construction regulations for the new constructions. The near zero energy houses are energy efficient and all the energy the house needs is developed with renewable energy. The new buildings that are constructed after 2020, are required to be near zero energy houses. The building energy efficiency can be affected especially in the preliminary phase of the building planning. To design an energy efficient house, different professionals need to work closely together. Designs should be made in interaction with designers and engineers and combining energy calculations throughout the process. If the energy efficiency is the goal, it is important to set it as an achievement in the requirement clarification phase (Lappalainen as cited in Kotilainen 2013). Using virtual reality could help with the common design work flow.

It is important to build energy efficiently in the cold environment like Finland. Besides good insulation, energy efficient doors and windows as well as air-tight frame, the shape, size and the orientation of the house are affecting the energy efficiency. Even a small house should be built into two floors, because the heat rises upwards. Passive sunlight energy can save in heating energy of the house. In the warm countries, preventing the sunlight heating the house should be blocked with vegetation and awnings, because air condition uses energy. One way to measure the Eco house is the constructors' calculator. It collects information about the house's structures and qualities such as if the house is a zero-energy house, does it have sun panels, collect rain water, how are the windows located and what heating system does the house have (Lappalainen as cited in Kotilainen 2013).

The most ideal shape of the house is a cube or a ball, when the houses exteriors ratio between the inner area is most efficient and energy loss and uncontrolled air ventilation are the lowest. However, this can be affected with a good insulation and making the building air-tight so the shape of the building can be other than a cube to have a zero-energy house. The amount of unnecessary and impractical heated spaces and energy consumption can be reduced with a good design. Usually these spaces are long hallways, too high ceilings, large staircases and impractical storage spaces. The benefit of energy efficiency is lost if the heated space has too many square meters compared per users. Lappalainen (2010) says that southern and western facades' window coverage should not be over 30% of the square meters and northern and eastern facades' windows shouldn't cover more than 10-15% of the square meters. (Lappalainen as cited in Kotilainen 2013). Even an energy efficient can be ecologically poor option if the living environment requires a lot of traveling between the services providers or a workplace or the space can't be adjusted to the living conditions of the inhabitant. The flexibility of the living spaces is going to be important that the user can change their home when their living situation changes. Changing furniture and space dividers could give solutions to make the spaces more flexible. Flexible house should be designed already in the designing phase. It could allow the resident to expand the needed square meter area or leave a part of the house without the heating (Lappalainen as cited in Kotilainen 2013).

Living trends

Housing construction recognizes the corresponding need and desire of individualism. It creates a question of how can we create individual, flexible spaces for changeable living habits in a socially, ecologically and economically sustainable way. The residential construction sector has not yet been able to supply large-scale serialization of real homes to apartment buildings, possibly due to the typical quality of the sector and the fragmentation of actors. Modular construction is a good example of the needed change in the production structure (Kotilainen 2013) In the year 1960, the average number of people in one residence in Finland was 3,34 people and in 2011 it had decreased to 2,07 people. The number of single people living in Finland has increased from 1.2 million to 2.5 million in 50 years. There are a lot of residences with one or two people and a couple can make a conscious choice of not making children. On average, families in Finland have 1.83 children. In 2010 the average built house size was 144 square meters. (Kotilainen 2013).

As an option to living alone or with a family, there has been rising numbers of co-living apartments. Prezza, Amici, Roberti and Tedeschi (2001) say that close contacts with the residential environment have been found to have in reverse effect for experiencing experiences and increase subjective well-being. In the future, there are more types of households that cannot be measured in one-dimensional charts. There will be more single-parent, reconstituted, same sex and mix generation families living together under the same roof in the future. The immigration will require more flexibility for the housing units. People who immigrate in Finland can have bigger families than the average family size is, and the houses should be able to accommodate it. The network possibilities have change the way we work and live. There are a lot more people working from home and a lot of the normal tasks can be performed virtually such as grocery shopping or reserving tickets online. The development of the technology could provide the possibility of not leaving from home and everything could be taken care from your own living room. At the same time, the mobility of people is increasing and a lot of people live in multiple places. In the future, we can see even more virtual reality blending together with reality and this can influence the housing solutions. Technology has made it possible for the time and place to become less tied together. Being able to work from home creates some demands for the living spaces (Heinonen & Saarimaa 2009).

Modular building

A module a relatively independent part of an entity that is interconnected and interchangeable with other modules. In the construction language, it can also mean a measurement. Modularity means that you can combine different modules together to get an end-product. Element structure construction means that the standardized building blocks have been manufactured in advance industrially and are transported to a building site for assembly. The advantage of prefabrication is small material losses and easier to recycle of the resulting building waste. Modular construction can reduce landfill waste by up to 70 percent. Under factory conditions, smooth working conditions and controlling job tracking minimizes mistakes. The number of reconstruction and repairs decrease. The state-of-the-art production makes it possible to build a building where resources, labor and materials are most easily and economically available. Quality of the work can be stable, because construction is not dependent on weather conditions. Since the foundations, building technical interfaces and the building itself can be built at the same time, shorten space element production substantially to the project lead time. On the other hand, the cost of the project is also more fully known, as the cost of a building contract is usually fixed and a short building time reduces cost risks (Kotilalinen 2013).

Canon 60-measurement system, oktametri, kantamoduuli 1M are made with modular system for building industry. Domino, Bungalow Oy “Kuten haluatte” and Moduli 225 are a few modular house models made in Finland. Nowadays the modules are built complete in the factory, delivered with a truck and mounted on top of the foundation. The base can be used, for example, for a steel pairs basis that is quick and easy to install. The weight of the modules does not limit the choice of foundations. After transporting the module house, water, drain and electrical connections, stoves and chimneys are installed and the electricity is switched on. After that, residents can change their own home. The ecological drawbacks of the modular building is the transportation of the modules. The delivery from the factory to the construction site produces emissions. The transportation and installation could require better strength from the structures against deformation. The transportation can require special arrangements and special equipment, and transport costs can be quite high (Kotilainen 2013).

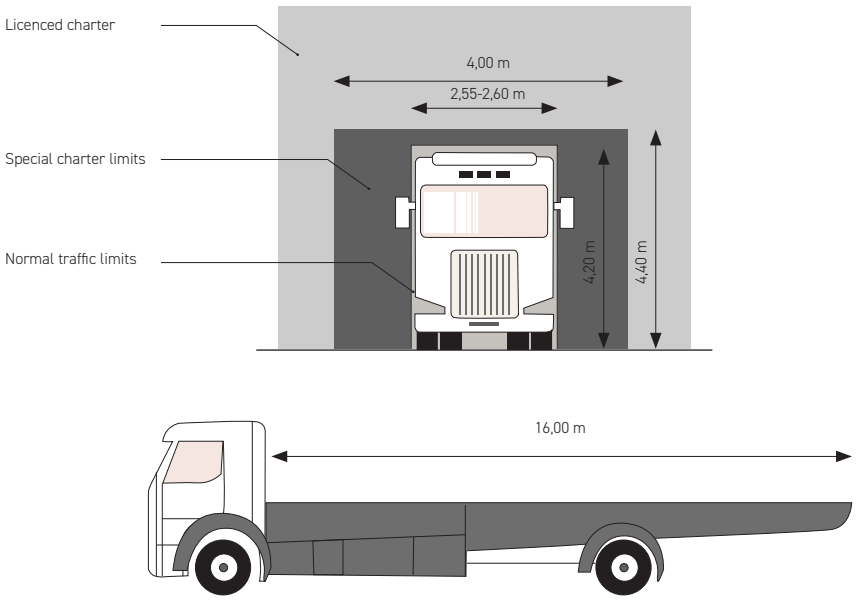

Fig. 37. Charter transportation (adapted from Ely keskus 2010).

Appendix 8. Diary

The design diary has been edited.

Week 1

Waiting to hear if the is a budget of the VR system.

Week 2

VR system HTC Vive was purchased and set up. I had a lot of issues with installing the graphics card and the software. I thought that I wasn't able to buy a VR system nor get it to work. My computer had a blue screen error and I spend two days repairing it. It was very frustrating. Unexpectedly, I needed to purchase a better graphics card for my computer. I have installed Unity but the user interface is very tricky. A great deal of instruction videos from the Internet have been watched such as videos on the Unity's website.

Week 3

A flyer for the housing fair was designed.

Week 4

Breakthrough! Design is now in VR mode in Enscape! I am very happy of the development. All the trouble with the blue screen errors and technology feels a bit better. I have been thinking about combining the knowledge from games designers and virtual designers in my thesis. I am using AutoCAD, Unity, Enscape, V-ray and Sketchup currently in the design process.

Week 1

I accomplished to get Loft Tilava imported in Unity and did my first C# script, however it didn't work. I found a service provider who provides a web platform for 360 images. It turns the images into the mode where you can show them to a client in VR. It is called SentioVR. This could work well for the MinunLOFT. I have been trying out different things in VR. I have needed watch a lot of tutorials and to learn how the software works. I think this might be the most boring phase. Learning of the software makes it helps to design later in the design development phase. I have been able to work with the model Avara in Enscape VR, it is now at a point where I am happy with the design in Sketchup. I have been working on the VR and understanding the process however I feel like everything is a bit chaotic still. VR has helped me to understand the design better. When I tried VR for the first time in Avara, I have changed the location of the walls, stairs and fixed furniture. I have changed the materials drastically. I am already seeing the benefits of using VR. It makes you see the design differently, to understand and feel the space.

Week 2

Loft Avara panoramic 360 images were rendered and downloaded to SentioVR. MinunLOFT web page will be updated with all the house models soon and the 360 tour will be available for clients to visit. I have started to work on the virtual model of Loft Ilmava, which now has suddenly become the most uninteresting one of the house models. Maybe it will change now that I start to work on it a bit more. VR has changed the way the design looks and made me question some of the previous choices that I have done.

Sentiovr is a Spanish company and three VR web page service costs $80 per month. MinunLOFT purchased the license to present the VR tours in their web page. I was also able to try out the Hololens for the first time. The housing fair started today so the new models are now being shown to the public. I've created a flyer, a magazine ad, web page content and a video for the fair. MinunLOFT organized a media day on Thursday with 400 media people visiting the MinunLOFT house. The web page has not yet been updated but it should be done next week.

Week 3

I rendered 360 images with V-ray from Loft Tilava. V-ray makes better-quality images but it takes much longer to render them. I done two posters for the housing fair. The web page changes were done this week but still without the 360 tours.

Week 4

This week has been spent in rendering images for Loft Tilava. I haven't been able to use VR this week.

Week 1

I have rendered all the 360 interior tour pictures and the interior 2d pictures for the website. Scale people added in Photoshop, pictures are updated in the website.

Week 2

I am starting to make client presentations about each of the three house models. VR has been used for the design decisions.

Week 3

Finishing up the design development phase.

Week 4

MinunLOFT client brochures have been updated, some web page work, updating pictures.

Results of the housing fair

The housing fair was toured by 134 543 people. MinunLOFT house attracted a lot of interest.